THE DECISION MAKING PROCESS IN THE ADOPTION OF AGROFORESTRY TECHNOLOGY BY SMALLHOLDER RUBBER FARMERS IN INDONESIA

A thesis submitted in partial fulfilment of the requirements for the Degree of Doctor of Philosophy

by

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Abstract

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The contribution of rubber to national economic and social development is important for Indonesia. However, smallholding rubber, the dominant rubber producer, has low productivity. Various new technology programmes have been introduced by the Indonesian government with other agencies to increase the productivity of existing traditional rubber and incomes among smallholder rubber farmers in Indonesia. However, the adoption of new technology was low and the reasons for these were still unclear.

This study explores how smallholder farmers in Indonesia adopt new technology. Rubber Agroforestry System (RAS) introduced mainly by International Centre for Research in Agroforestry (ICRAF) in Jambi and West Kalimantan provinces in Indonesia is used as a case study. A combination of Ethnographic Decision Tree Modelling (EDTM) proposed by Gladwin (1989a) and a logistic regression model were used as the main methodologies to determine the decision criteria of rubber farmers regarding adoption of clonal rubber. The EDTM as qualitative method helped to identify the main reasons, motivations and constraints that influenced a farmer's decision to adopt or not adopt the new technology and also present details about the process of the farmers' decision making. Meanwhile, logit as the quantitative method was useful to identify the significant variables involved in the decision making process.

The results of this study show that the decision making process for adoption of clonal rubber is complex and influenced by various factors. The decision tree models for Jambi and West Kalimantan differed showing the importance of social context and infrastructure. The main reasons for a farmer's decisions to adopt clonal rubber is the expectation that clonal rubber is better in growth and yield and it will increase production per ha and income. The decision to adopt is supported by evidence from demonstration plots, trust in the technology deliverers and availability of incentives. The main constraint in adoption for both areas was limitation of capital as the clonal rubber required more capital to establish. The other constraints are risk and uncertainties including pest and disease problems, the shortage of labour, lack of technical knowledge, lack of access to clonal seedlings, and observation of clonal rubber that has been of low quality or managed inadequately. The decision tree models have been tested and the results show that the models were able to predict the farmers' decision making with good accuracy of 82% and 83%. In addition, the quantitative model shows the significant factors that determine adoption of clonal rubber in Jambi and West Kalimantan are land, incentives and income factors.

The qualitative and quantitative methods contributed to increased robustness of data and give different kinds of valuable data and information to stakeholders and policy makers in Indonesia. In order to encourage rubber farmers in Jambi and West Kalimantan to adopt clonal rubber, this study suggests improving policies to ensure they are aligned with needs of the rubber farmers, improving farmers' access to capital sources such as credit with simpler mechanisms, increasing the number and skills of extension workers, encouraging farmer to farmer learning, empowering farmers and leadership, improving infrastructure including better access to clonal seedlings and improving partnership with NGOs.

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List of Abbreviations

BPS	(Biro Pusat Statistic = Statistics Centre Bureau)
BAPPEDA	Regional Body for Planning and Development
CIFOR	Centre for International Forestry Research
DGECI	Directorate General for Estate Crops of Indonesia
DFECS	District Forestry and Estate Crops Services (Dishutbun)
GDRP	Gross domestic regional product
IRRI	Indonesian Rubber Research Institute
IDRB	International Development & Relief Board
ICRAF	International Centre for Research Agroforestry
NES	Nucleus Estate Smallholders
NGO	Non Governmental Organizations
NSSDP	Projects include North Sumatra Smallholders' Development
PRPTE	Replanting Rehabilitation and Expansion of Export Oriented Commodities
PPKR	People's Rubber Plantation Project
RAS	Rubber Agroforestry Systems
SRDP	Smallholders' Rubber Development Project
WSSDP	West Sumatra Smallholders' Development Project

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Chapter 1 Introduction

1.1 Background

Indonesia has the world's largest area of rubber plantations (3.4 million ha) and is the world's second largest rubber producer with about 2.7 million tonnes in 2007 (DGECI, 2008). Most of the rubber plantation is in an agroforestry system - a jungle rubber system usually operated by smallholder farmers (<5 ha) - rather than the monoculture system which is adopted by big estates. Rubber latex produced by smallholders is high, around 79 % of the total natural rubber production or about 85% of the total rubber area (DGECI, 2008).

Rubber agroforestry is economically, socially and environmentally important for the rural people in Indonesia. It provides the main income source, employment opportunities and food for local people and also has an important role in the environment, such as in the conservation of biodiversity and water sources. However there are some problems in the sustainability of rubber agroforestry in Indonesia, such as productivity being generally low compared to monoculture rubber. Limitations in the application of technology and good management are possibly the causes of this low production.

The Indonesian Government and various Non Governmental Organizations (NGOs) have introduced some programmes that may help the existence and productivity of smallholder rubber farmers. The main goal of the projects has been to increase the yield and quality of rubber trees through the introduction of high yielding rubber clones and their management under various schemes. The introduction of technology in agroforestry is needed in order to (1) increase the yield and quality of rubber trees through the introduction of high yielding rubber clones, (2) diversify products from rubber agroforestry by combining rubber with high value crops, and (3) increase the conservation services of rubber agroforest.

The introduction of improved agroforestry technologies to smallholder farmers in Indonesia has potentially shown positive effects in terms of the number of trees on each farm as well as local people's income from diversification of trees and crops. These technologies will have a greater impact on land productivity and farmers' incomes if most farmers adopt them. For example, the use of clonal planting material is important to increase the latex productivity of the traditional rubber agroforestry system among smallholder rubber farmers in Indonesia. There are technical, economic and social challenges associated with conversion from a traditional to an improved system. Although the benefits of clone-based technology are significant and there have been efforts to promote it, its adoption by farmers has been limited. Many internal and external constraints can affect adoption of these technologies by farmers including their potential impacts on rubber production and income. There is growing concern that some projects of agroforestry technologies in parts of the world have failed and technology adoption rates have been limited (Kiptot et al., 2007).

Often the underlying reasons farmers adopt or do not adopt certain technologies remain unclear. Therefore, it is essential to understand how farmers make decisions, what pattern they follow and what criteria and constraints they face in the adoption of new technologies. Only with this understanding can more appropriate technologies and more effective approaches in agroforestry be implemented.

1.2 Study Objectives

The objectives of the study are:

1. To conduct a detailed analysis of the decision making process in technology adoption by smallholder rubber farmers in Indonesia
2. To identify the main social, cultural, economic and policy factors that influence smallholders in making decisions on technology adoption
3. To review the introduction of technology in a rubber agroforest system (RAS) project and its adoption process by smallholder farmers.
4. To develop predictive models of farmers' adoption of new rubber technologies in Indonesia.

The following are the research questions and areas explored:

1. Why do smallholder farmers adopt or not adopt new technology? What are the main factors that influence smallholders' decisions? Are economic factors dominant in farmers' decisions to adopt or reject technology? How influential is infrastructure in the study area? What is the role of social and cultural factors in the adoption process? What is the decision making process followed by farmers?
2. Can the real adoption process taken by smallholder farmers be modelled using a cognitive model based on ethnographic data collection in which farmers' decision criteria are identified through hierarchical processes?
3. Do farmers appear to follow a logical process in making technology adoption decisions, and is their rationale influenced by factors such as technology characteristics, technical and socioeconomic, farm and farmer characteristics, their socio-cultural influences as well as institutional factors?
4. Is a quantitative modelling approach using logit analysis complementary to a qualitative approach using the ethnographic decision tree model?

The objectives of this study will be accomplished through exploring the decision making process of smallholder farmers towards new agroforestry technology adoption. This study is based on the case study of the project dissemination of the Rubber Agroforestry System (RAS) that was developed and promoted by the World Agroforestry Centre (ICRAF) in Jambi and West Kalimantan provinces, Indonesia. The project incorporates clonal rubber to replace traditional unselected seedlings in a traditional rubber agroforestry setting to improve latex productivity while maintaining the benefits of the traditional system. The respondents were smallholder rubber farmers in these two provinces. By using a combination of qualitative and quantitative approaches in the data collection, processing and analysis, this study aimed to carry out a detailed analysis of the decision making process in technology adoption by smallholder rubber farmers in Indonesia.

1.3 Main Contributions

The study of the adoption of agroforestry technology by smallholder farmers is important, especially in order to increase production and farmers' incomes. In Indonesia studies on the adoption of agroforestry technologies, specifically the process of a farmer's decision to adopt or not adopt technology, are still limited. Most studies are of agricultural or annual crops which are different from agroforestry. In the context of agroforestry, adoption studies need to address more complex management requirements as the application of agroforestry technology, such as clonal rubber, requires longer periods of time for testing and modification than technology for agriculture.

The importance of a study of agroforestry adoption has been emphasised by some scholars. Agroforestry technology will have significant impacts on land management, productivity and farmers' incomes, but only if it is adopted by most of the farmers in the area (Raintree, 1983). In order to increase the adoption of agroforestry technologies, we need to understand how and why farm households make decisions regarding land use (Mercer, 2004; Sanchez, 1995). This study can contribute to understanding the decision making process of smallholder farmers regarding the adoption of new technologies for their land.

Theoretically and practically the study will contribute to the improvement in research, agricultural extension and policy approaches. Knowledge of the farmers' decision making process may help policy makers in Government bodies, researchers and extension workers to create and deliver better policies, research and assistance to farmers, based on what farmers need and face. By knowing the decision making process followed by farmers to deal with new technology introduced to them, it may be useful for extension workers or researchers to introduce new technology with different approaches based on processes that most farmers follow to get optimum results. Farmers also differ in the process of adoption and the study may identify the different factors influencing each stage or year in the process. This information may be used to intervene with some activities to accelerate the adoption process to optimize the results of adoption.

This study may contribute to better planning, design and implementation of new technologies for farmers in future projects, particularly in Indonesia. Therefore, it will be of benefit to the development of more appropriate agroforestry technologies and methods that can be adopted by smallholder farmers.

1.4 Organization of the Thesis

The next chapter provides a brief overview of rubber in Indonesia, including its history and role in the Indonesian economy, and problems with traditional rubber productivity. This chapter also highlights the introduction of new rubber technology, the characteristics of new technologies and reviews the background to technology adoption among farmers in Indonesia.

Chapter 3 presents a general overview of the theoretical and empirical literature on the diffusion and adoption of new technologies that underlie the objectives of this study. Factors influencing adoption in previous empirical studies in developing countries and models that can be used to analyse decision making, including qualitative and quantitative approaches, are reviewed.

The study sites, the methodology for data collection, processing of data and the procedures of the analyses for this thesis are presented in Chapter 4 and the results are presented and discussed in Chapters 5, 6, 7 and 8. Chapter 5 presents the results of the decision tree model in the adoption of clonal rubber by smallholder farmers in Jambi. Meanwhile Chapter 6 explains the decision tree model in the adoption of clonal rubber by smallholder farmers in West Kalimantan. Further, chapter 7 presents a discussion and comparison of the adoption of the new agroforestry technology model in West Kalimantan and Jambi. Chapter 8 presents the results from the quantitative analysis of the adoption of clonal rubber by smallholder farmers in those two provinces. Finally, Chapter 9 concludes this thesis by presenting a summary of the key findings from this study, as well as implications and suggestions for the future direction of research.

Chapter 2 Rubber Agroforestry Technology Adoption in Indonesia

2.1 Introduction

This chapter will present the background of rubber agroforestry in Indonesia, its role and problems and how to turn them into the inspiration for this study. The chapter begins with the history and development of rubber agroforestry and how it became integrated into the local traditional farming system in Kalimantan and Jambi. It then discusses the role of rubber as one of the most important contributors to the economic development of Indonesia leading it to become the second largest rubber producer in the world. This chapter also highlights the problems with rubber productivity, followed by the way the Government and other agencies have introduced programmes to increase the productivity of rubber and farmers' incomes. However there have been problems concerned with the low adoption of the new technologies which highlighted the need for research to discover the constraints on adoption. This chapter ends with a summary.

2.2 Forest and Rubber Agroforest in Indonesia

Indonesia is a large country, rich in natural resources and covering 1,811, 570 km^2. There are more than 17,500 islands of which 6,000 are inhabited and 1,000 permanently settled. There are 30 provinces and the population of approximately 230 million in 2007 makes it the world's fourth-most populous nation. The island of Java is the most populous island in the world (124 million, 2005 est.) and one of the most densely populated areas in the world. Like most developing countries, Indonesia still depends on its natural resources such as forest, ocean, coal, oil and natural gas for economic needs. Indonesia, with rain forest covering almost 134 million ha, has the world's second largest forest area, after Brazil, and accounts for about 10 percent of the world's remaining tropical forest (Pagiola, 2000).

However the forest area in Indonesia has been decreasing for various reasons. It is difficult to point to the main causes of the deforestation as they include natural, human, social, economic and political aspects. Deforestation in Indonesia may be caused by: (i) shifting cultivation, by both indigenous groups and by new migrants; (ii) clearing for agricultural use, and particularly for tree crops; and (iii) logging (Sunderlin and Resosudarmo, 1996). Potter and Lee (1998) also categorised the causes of deforestation as logging and road building, forest fire and shifting cultivation by indigenous people and migrants.

Shifting cultivation is a traditional agricultural method that has been established by Indonesian farmers over a long period. Usually they used it to develop agricultural land. However in some places this was also used to establish not only subsistence crops but also tree crops. Smallholder tree crop production is often understood to be included within the general term shifting cultivation, because many shifting cultivators produce tree crops. It should, however, be seen as a distinct category because, although it is strongly associated with shifting cultivation, it tends to be carried out on different kinds of lands and follows an entirely different logic of production (Dove, 1993).

From the point of view of the local people in and surrounding the forest, the forest has an important role in their life as a source of income, food, shelter, medicine, culture, water and land. As a land source, the forest was cleared and used for agricultural purposes, cultivation of food and tree crops. Rubber, coffee, coconut and oil palm were popular commodities in Indonesia that were cultivated in cleared forest land. In some provinces conversion of forest to tree crops by local people has become important. Conversion of the forest to rubber can be assumed to be deforestation because the forest has been changed to agricultural and tree crops for the main source of income for local people (Chomitz and Griffiths, 1996). However most of the rubber plantation is in the "jungle rubber" system. Jungle rubber is defined as "*a balanced, diversified system derived by farmers from swidden cultivation, in which man-made forests with a high concentration of rubber trees replace fallows*" (Gouyon et al., 1993, p.181). Conversion to jungle rubber tends to conserve the forest's biodiversity as plant biodiversity in old jungle rubber is close in richness to old secondary forest (Michon and de Foresta, 1995b). This is characterized by the rich biodiversity which includes trees and animals that can live and grow in the jungle rubber.

2.3 History of Rubber in Indonesia

Originally the rubber tree (*Hevea brasiliensis*) was indigenous to the Amazon forest in Brazil. In 1876-1877 it was brought to England by Sir Henry Wickham. Some of the seeds were later sent to the Botanical Garden in Java, by the Dutch government (Coates, 1987; Tengwall, 1945). However the first seeds in large numbers for plantation in Indonesia came from plantations that were already established in Malaya and Ceylon before 1900 (Tengwall, 1945).

Even though Java was the first island to receive the rubber seed, Sumatra has a more developed history in the establishment of rubber plantations. Rubber plantations were first established in Sumatra by the Dutch government in 1906 and then spread into north and south Sumatra in 1910-1920, not too long after the establishment of the first estate. The rubber seed spread to the people in Kalimantan through Malaysian and Chinese traders as well as Catholic missionaries in 1908-1909. Rubber became popular in some places in Indonesia and was extensively developed and adapted to the traditional farming systems in Sumatra and Kalimantan. The boom in rubber in Indonesia began in the years 1910-1912, mainly caused by an increased demand for rubber, especially linked to the automobile industry in the USA and economic recovery after World War I (Tengwall, 1945). The price was good and as a result rubber plantations increased rapidly to fulfil the demand. From before World War II until 1959, Indonesia was the largest producer of rubber in the world. Then, starting from 1959, Malaysia became the number one producer, as this country started replanting and developed new plantations on a large scale by using high yield improved clonal seedlings.

There are several studies indicating the reasons behind the popularity of rubber adopted by smallholders in the two areas of Jambi and Kalimantan. Basically the reasons can be categorised as suitability of soil and climate and land availability as well as social, economic and environmental factors, as discussed in more detail below.

1. *Suitability of soil and climate*

Rubber requires a warm and humid climate for optimal growth, thriving best in latitudes close to the equator (Barlow et al., 1994) such as Sumatra and West Kalimantan. Soils in West Kalimantan have relatively good physical characteristics but poor chemical value; however rubber is widely known to grow in poor soils. For rubber the physical characteristics of the soil are more important than its nutrient status (Delabare and Serier, 2000). In addition, rubber also can grow in hilly areas even on high steep slopes (Delabare and Serier, 2000) which dominate in some areas in Sumatra. Generally areas in West Kalimantan have an annual rainfall of 2,500 mm in almost all years, which is suitable for rubber trees to grow (Barlow and Muharminto, 1982; Delabare and Serier, 2000). In addition there are no diseases such as occurred in Brazil where rubber originated.

2. *Land availability*

In the past, some provinces such as Jambi, South Sumatra and West Kalimantan had relatively large land and forest areas available for planting rubber. Land suitable for cultivation is relatively abundant in most smallholding areas (Barlow and Muharminto, 1982). In the 1910s and 1920s, Sumatra and Kalimantan were less populated, with 1-4 inhabitants /km^2 (Penot, 2004). This led farmers to carry out extensive rubber farming, as every rubber plantation was counted as land in traditional ownership. Rubber was ideal for people with enough family labour to slash and burn a few hectares of forest and to plant rubber (Barlow et al., 1994).

3. *Socio cultural*

Rubber suited the socio cultural ways of farmers in Sumatra and Kalimantan, as when rubber was introduced to these islands it was adapted to the traditional farming system of slashing and burning forest (Tengwall, 1945) for the cultivation of food crops by the extensive swidden system (Dove, 1993; Dove, 1996). After the forest was cleared the farmers planted paddy rice (*Oryza sativa*) for two years for their staple food. After that they abandoned it for several years before coming back to use it again for another period of paddy rice and then secondary forest growth occurred naturally. When the rubber was introduced to the farmers, rubber seed was planted mixed up with paddy rice (Gouyon et al., 1993). Rubber can be planted at a high density together with other crops and trees. Rubber grows naturally in the shade and may compete with other trees and shrubs to form secondary forest. After 10 years of growth, farmers can tap or extract latex from rubber trees for around 30 years or more.

As the rubber is suited to their traditional swidden system, farmers can manage rubber together with their activities in the swidden, especially paddy rice. When they are not busy on their farm they can use their time to manage rubber. But at the peak of their farming activities, such as planting or harvesting, they will spend less time on the rubber (Dove, 2002). The farmers manage rubber, agricultural crops, timber trees and fruit trees that were planted or grow naturally together in their land and these products become important for their daily needs and income sources. The farmers can harvest rubber and other non rubber products such as timber, fruits, rattan, herbs and medicinal plants. Because they can manage rubber plantations in the jungle rubber system and they get various products from this system, they did not plant rubber in a monocultural and intensive system. They believed managing rubber in a forest format could save the rubber from pest and disease attacks (Dove, 2002). In addition by planting in high density forest, old and unproductive rubber can be replaced by natural succession from the secondary growth of rubber. They do not need to replant and can save their time, labour and cash.

Rubber is suitable for farmers' social structure. Men and women can work together on rubber activities. In this rubber management men are responsible for land clearing, planting and fencing and women are involved in tapping and weeding (Dove, 2002). This is important as family labour is the main source of labour for rubber activities. In addition, the transformation from forest to jungle rubber was also suited to the traditional regulation that clearing forest and planting with trees give the farmers property rights over land. Planting agricultural crops just maintains ownership temporarily as they have to return the land to the community after the cultivation years are finished (Murdiyarso et al., 2002)

4. *Economic*

Economically rubber is also suitable for smallholder farmers. Smallholders are agricultural farmers who traditionally cultivate food crops for their daily life; they combine them with rubber on their land to meet their need for cash (Dove, 1993; Gouyon et al., 1993; Tengwall, 1945). Rubber has been shown to be a better source of income compared to other crops or other forest products (Tengwall, 1945) and gives a higher income than ladang (traditional swidden crops) (Gouyon et al., 1993). In addition, rubber can be tapped, stored and sold at any time during the year which makes it certain that farmers get the cash when they need it (Sunderlin et al., 2000). In West Kalimantan, farmers tap fifty to a hundred or more trees per day, depending on the sizes of their rubber holdings and their cash needs (Peluso, 2007). In addition, rubber has better access to the market compared to other commodities. The market for rubber is relatively available as the world's demand for rubber has tended to increase and become more flexible, so the production of latex can be managed based on the price in the market (Dove, 1993). If they need more cash and the price is high, usually farmers increase production by tapping more rubber trees or more often than usual. Stopping tapping does not affect the productivity or quality of latex but it gives time for rubber trees to recover. In this situation farmers usually concentrate more on their farming activities (Dove, 1996) or other temporary jobs such as fishing and hunting.

Jungle rubber is suitable for farmers in Sumatra and West Kalimantan, as it is easy to prepare, to grow and to harvest (Tengwall, 1945). It is relatively low cost in establishment and management. Establishment costs are low as farmers clear the land using the same process as for paddy rice, using free unselected seedlings, no or less weeding and no fertilising (Penot, 1996). During the immature period, rubber has no or low maintenance as the farmers let the rubber trees grow together with other trees and crops, and only return when rubber trees become mature and ready to be tapped. As the costs in establishing and maintaining rubber trees are low compared to other commodities, this is important for farmers who have limited access to capital

(Sunderlin and Resosudarmo, 1996; Sunderlin et al., 2000). Jungle rubber is also appropriate for farmers who have limited labour, cash, technical knowledge and other input support such as fertilisers and pesticides.

5. Environmental

Jungle rubber also is an environmentally suitable land use because it is principally old secondary forest and the function is similar to that of primary forest (Chomitz and Griffiths, 1996). The forest in Indonesia, especially in Sumatra and Kalimantan, is rich in biodiversity and is one of the world's 'mega-diverse' countries with 60-70 % of total global biodiversity. In comparison, jungle rubber also has high biodiversity, less than primary forest but higher than intensive and monocultural rubber estates. In complex agroforestry systems, a high number of components and functions are close to natural forest ecosystems, either primary or secondary forests (Michon and de Foresta, 1995a). Several studies found that the sample jungle rubber sites in Indonesia contained tree species, lianas, epiphytes and different types of birds that were less diverse than in primary forest, but generally far higher than biodiversity in monocultural rubber plantations (Beukema et al., 2007). This environmental function of jungle rubber becomes beneficial in conserving biodiversity and to support the life of local people.

2.4 The Role of Rubber in Indonesia

As mentioned before, rubber is suitable biophysically, socially, economically and also environmentally, thus jungle rubber extends over a land area of more than 2.5 million ha in the forests of Kalimantan and Sumatra (Joshi et al., 2003) and has become the dominant land use in Sumatra and Kalimantan (Dove, 1996). South Sumatra has the largest rubber plantations in the country, which in total were 595,000 hectares in 2004 which is 22% of the total area in the country, followed by Jambi (15%), Riau (13.5%) and West Kalimantan (13%), see Table 2.1. Meanwhile in Java most of the rubber plantations are dominated by Government owned (BUMN/PTPN) and private estates. Smallholding rubber plantations involve millions of rubber farmers and an estimated 7 million people depend on them for their main source of income (Joshi et al., 2003). Around 70% of farmers in Jambi are involved in rubber based agroforestry with an estimated 70% of their household income coming from the production of rubber from their land (Wibawa et al., 2005a; Wibawa et al., 2005b). Rubber plantations also provide employment in rubber processing and related rubber industries and over one million families are involved in the Indonesian rubber industry (Barlow and Muharminto, 1982). These rubber smallholdings, government estates and private estates have contributed to the economic development of Indonesia.

Table 2.1 Area and production of smallholding rubber by provinces in Indonesia in 2004

	Province	Area (000 ha)	Production (000 tonnes)	Production (%)	Area (%)
1	South Sumatra	595	349	21.4	22
2	Jambi	412	205	12.5	15.2
3	Riau	366	223	13.5	13.5
4	West Kalimantan	354	194	11.8	13.1
5	North Sumatra	293	244	14.9	10.8
6	Central Kalimantan	240	164	9.9	8.9
7	South Kalimantan	109	57	3.5	4
8	West Sumatra	98	67	4.2	3.6
9	Aceh	71	44	2.6	2.6
10	Bengkulu	58	32	1.9	2.1
11	Lampung	50	27	1.6	1.8
12	East Kalimantan	34	19	1.1	1.3
13	Bangka Belitung	29	19	1.1	1.1
	Total	2709	1644	100	100

Sources : Directorate General for Estate Crops Indonesia (DGECI, 2008)

Rubber has played a significant role in Indonesia's economic development. Estate crops in Indonesia contributed significantly to the GDP (Gross Domestic Product) of the agricultural sector as rubber exports earned US$ 6.057 billion in 2008 (Rahman and Haris, 2009b). Most of the rubber production is export oriented as raw material with only a small part for domestic use, and there are around 218 rubber related industries such as the tyre industry (Rahman and Haris, 2009a). The two main products of rubber are latex and wood of rubber trees. Latex from natural rubber has a variety of uses in industries such as for the automotive industry, (tyres, parts, belts) health and medical industries (condoms, gloves), property, the footwear industry, electronic and other related rubber products. The wood of rubber trees also can be used to produce processed wood products such as moulding, particle board, wood flooring and furniture.

In 2007 the country's production totalled 2.8 million tonnes, only 0.4 million tonnes of which were used for domestic industries and around 2.4 million tonnes were exported to other consumer countries. The main consumers of rubber are China, European Union, USA, Japan and India. Exports have fluctuated and increased from 1.5 million tonnes with a value of US $782 million in 2001 to 2.3 million tonnes with a value of US $6.1 billion in 2008 (see Table 2.2).

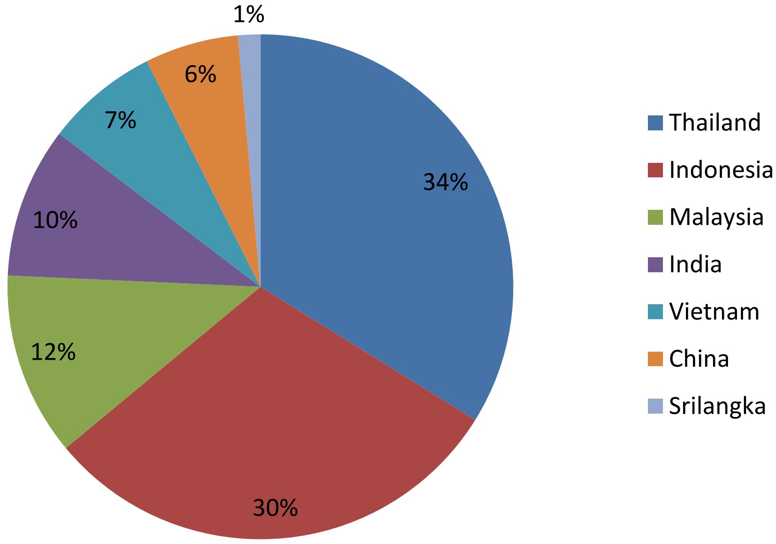
Table 2.2 Production and export of rubber in Indonesia (2001 – 2008)

	Year							
	2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Area (,000 ha)	3,345	3,318	3,290	3,262	3,279	3,346	3,414	3,470
Production (000 tonnes)	1,607	1,630	1,792	2,066	2,271	2,637	2,755	2,751
% of the world's production	22.3	22.8	23.3	24	25.3	27.2	27.9	27.8
Export (000 tonnes)	1,453	1,497	1,661	1,874	2,024	2,287	2,407	2,295
Value (Million US$)	782	1,039	1,494	2,180	2,583	4,321	4,867	6,057
Domestic consumption (000 tonnes)	142	145	156	196	221	355	391	414

Sources : Directorate General for Estate Crops Indonesia, (DGECI, 2008; Rahman and Haris, 2009a)

Indonesian rubber has an important role in the world. The major producers of rubber in the world are Thailand, Indonesia and Malaysia. India and China also produce natural rubber in huge quantities, but most of their production is to fulfil their domestic needs. Indonesia has the largest planted rubber area compared to other producers and is the second biggest producer behind Thailand (see Figure 2.1).

The world's demand for natural rubber is predicted to increase in the future. This is mainly because the economic growth of countries such as China, India, South Korea and others has influenced rubber demand. China has been the biggest consumer of natural rubber owing to the expansion in this country of the automotive and consequently the tyre industry. China has replaced the USA and Japan as the world's largest rubber consumer. Natural rubber, as the alternative to synthetic rubber made from oil, has opportunities in the future as oil prices will continue to rise. It is predicted that in the year 2035, 31million tonnes (of which 15 million is predicted to be supplied by natural rubber) will be needed to supply the various rubber related industries especially tyres, and also the automotive and household equipment industry (Anwar, 2006).



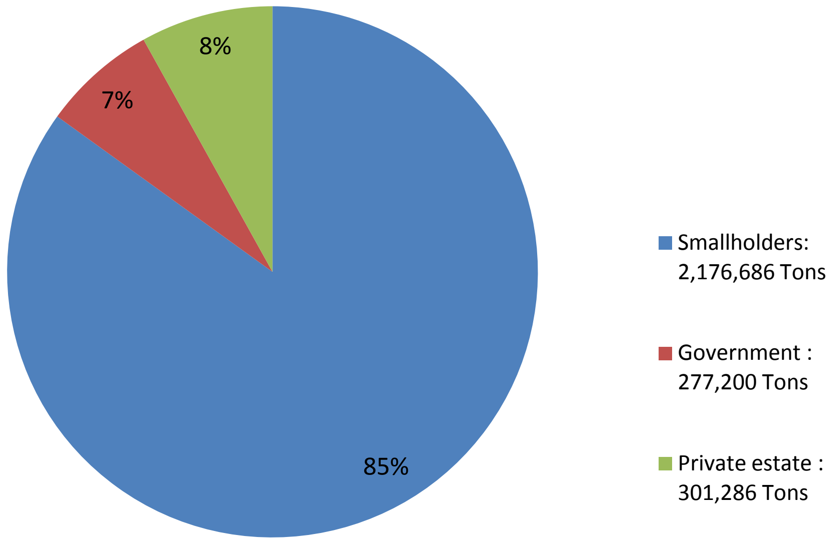
Source: Association of Natural Rubber Producing Countries (ANRPC, 2010)

Figure 2.1 Rubber producing countries and percentage of world production (2008)

To fulfil this demand and to increase its economic sector, Indonesia is projected to produce 3.5 million tonnes in 2015, 3.8 million tonnes in 2020 and 5.1 million tonnes in 2035, mainly through replanting, new plantations and increasing the use of improved high yield clonal seedlings (Anwar, 2006).

2.5 Rubber Agroforestry: Position and Problems

In 2007, the total rubber area in Indonesia was 3.4 million hectares, and small-holdings made up 85% of natural rubber plantations in the country, compared to Government (8%) and private estates (7%), see Figure 2.2.



Source : Directorate General for Estate Crops Indonesia, (DGECI, 2008)

Figure 2.2 The percentage of the area and annual production of natural rubber based on type of management

The world demand for rubber is an opportunity for Indonesia as one of the leading producers of natural rubber. Indonesia has the potential to extend its rubber plantation owing to availability of land and labour. However some problems and constraints in rubber production in Indonesia resulting in low production per hectare need to be overcome.

Table 2.3 Area and production of rubber by smallholding, government estate and private estate.

Year	Area (000 Ha)				Production (000 Tonnes)			
	Smallholders	Govt	Private	Total	Smallholders	Govt	Private	Total
2000	2,883	213	277	3,372	1,125	170	206	1,501
2001	2,838	222	284	3,345	1,209	183	216	1,607
2002	2,825	221	272	3,318	1,227	187	217	1,630
2003	2,772	242	276	3,290	1,396	192	204	1,792
2004	2,748	239	275	3,262	1,662	196	208	2,066
2005	2,767	238	275	3,279	1,839	210	222	2,271
2006	2,833	238	275	3,346	2,083	266	289	2,637
2007	2,900	238	276	3,414	2,177	277	301	2,755
2008	2,944	246	280	3,470	2,308	294	320	2,922
2009	2,997	247	281	3,525	2,402	306	332	3,040

Source: Directorate General for Estate Crops Indonesia,(DGECI, 2008)

Productivity is much lower compared to the productivity rate of smallholdings in other rubber producer countries. In India it can reach 1.9 tonnes/ha/year and Thailand 1.6 tonnes/ha/year (Parhusip, 2008b). Probably this is because those countries have historically been more intensive than Indonesia (Joshi et al., 2006). For example, Thailand has the highest production of rubber with 80% of smallholder plantations using high yield clonal rubber (Sukem et al., 2005).

According to Suryana (2005) the low productivity of smallholder plantations in Indonesia is due to the rubber farmers still largely planting unimproved rubber seedlings and a large proportion of the smallholder plantations consisting of old and unproductive rubber trees. Other factors that influence the productivity of rubber are the fertility status of the soil and nutrients but these have less influence on the rubber latex yield (Akpan et al., 2007). The application of clonal seedlings followed by improved practices indicated an average rise over unselected seedlings of 24%, from 5.8 to 7.2 kg/ha (Barlow and Muharminto, 1982). A study in South Sumatra showed that the average production of latex differs between clonal and local seedlings. The clonal rubber has an average yield 90 % higher than the local. Latex yield from the clonal ranges from 35 to 41 tonnes per hectare, while the maximum yield from local seedlings is only 21 tonnes per hectare with a minimum of 19 tonnes (Purnamasari et al., 2002). The average production of a smallholding is around a maximum of 0.4 - 0.8 tonnes/ha/year, meanwhile Government and estate plantations can reach to 1 to 1.8 tonnes/ha/year (Joshi et al., 2006, Joshi et al., 2002; Parhusip, 2008).

As the smallholder system is based on traditional jungle rubber, the rubber trees tend to grow naturally without intensive maintenance. As a result, regeneration is only by natural processes, so most of the rubber trees are old and high in density. Sometimes in the field there is still available rubber which is 60 years old (Mulyoutami et al., 2009). Normally rubber has a productive age of 30-35 years and after that production tends to decrease. Most smallholder farmers are continuing to tap the old rubber to get cash to fulfil their daily needs and they do not have enough capital for rehabilitation and replanting with clonal rubber.

The low rubber production is also related to lack of inputs including fertilisers and pesticides which are unavailable or too expensive. The other possibilities include lack of technologies as most rubber smallholders in Indonesia still use the original simple technology of the 1900s and lack management skills as well as new technologies (Barlow, 1996). These problems are also linked to limitations in the rehabilitation and replanting programmes and to socio economic factors. The topic of the introduction of technologies to increase rubber productivity and the problems in adoption will be further addressed in the next section.

2.6 Introduction of Improved Technologies in Rubber Agroforestry

Although in Malaysia replanting of smallholders' rubber with highly improved clonal rubber was started in 1959, in Indonesia there was only a small improvement in the rubber productivity program until the 1960s, owing to instability in the political situation (Barlow, 1997). From the 1970s, there were some programmes for the development of smallholding rubber to increase the production as well as to enhance the livelihood of rubber farmers. Various projects of the Indonesian government, Non Governmental Organisations (NGO), research centres, and other institutions were launched to help smallholder farmers. The projects had different schemes but mostly had the main objective of increasing the yield and quality of rubber trees through the introduction of high yielding rubber clones. Some projects offered credit to farmers for land clearing, planting, and maintaining immature rubber with fertiliser to support their growth and pesticides to control pests and diseases.

The Government and international organisations have been involved in various projects to increase the productivity of smallholder farmers in Indonesia (Barlow and Muharminto, 1982; Peluso, 1993; Penot, 1996; Penot et al., 2002). The projects included North Sumatra Smallholders' Development Project/West Sumatra Smallholders' Development Project (NSSDP/WSSDP) sponsored by the World Bank, Nucleus Estate Smallholders (NES), Smallholders' Rubber Development Project (SRDP) also sponsored by the World Bank and the Asian Development Bank. The other projects were Replanting Rehabilitation and Expansion of Export Oriented Crops Project (PRPTE) and People's Rubber Plantation Project (PPKR).

Projects such as the PPKR have been successful, especially for those who could afford the labour inputs and the credit (Peluso, 1993). However, most of these projects had limitations in covering the large number of smallholder areas in Indonesia. In the 1980s, only 8 % of rubber farmers were affected by government rubber programmes and this increased to 16 % in 2002 (Penot, 2004). These projects were mostly concentrated in certain areas and focused only on the project farmers' areas and less attention was paid to non project farmers (Barlow and Muharminto, 1982). As a result large numbers of smallholding rubber areas are still using unselected low yield seedlings and traditional management of rubber.

In 1994 the Improved Rubber Agroforestry System (RAS) was developed and promoted by the World Agroforestry Centre. This Centre was established in 1978 as the International Centre for Research in Agroforestry (ICRAF) and the Southeast Asia program was established in 1993 with Indonesia as its regional headquarters. ICRAF's objectives focus on carrying out strategic and applied research in partnership with national institutions aimed at developing suitable agroforestry technologies for more sustainable and productive land use.

ICRAF has been involved in research and support activities in the smallholder rubber sector in Indonesia, especially in Jambi, West Kalimantan, West Sumatra and South Sumatra, through the Smallholder Rubber Agroforestry Project. The Rubber Agroforestry System (RAS) in Indonesia started in September 1994 and continued until 2004. It was introduced as a joint project run by ICRAF and other local and international organisations. The locations of the project are in three selected provinces: West Kalimantan (Sanggau and Sintang areas), Jambi (Muara Bungo), and West Sumatra (East Pasaman area). This project is intended to increase productivity of jungle rubber, but still keep its ecological and environmental benefits, through the participation of rubber smallholders. It integrates clonal rubber in a traditional agroforestry setting to improve latex productivity while maintaining some benefits of the traditional system. There are three types of RAS that have been introduced to rubber farmers:

RAS 1. Productive jungle rubber.

In RAS 1 natural vegetation re-growth is promoted between rows of clonal rubber trees for maintaining favourable conditions for rubber growth while keeping noxious weeds such as *Imperata cylindrica* under control. This RAS aims to increase productivity by introducing clonal rubber planting material in the forest environment while reducing maintenance costs and recreating an environment similar to jungle rubber.

RAS 2. Complex rubber agroforestry system.

In RAS 2, fruit trees and other crops can be grown between rubber rows with two cycles of upland rice, and then other crops such as chilli, maize and banana are planted in the first period. RAS-2 combines rubber trees with other high value timber and fruit species.

RAS 3. Reclaiming Imperata *grasslands*.

RAS 3 has been developed for rehabilitating *Imperata* grasslands with clonal rubber. In this system, legumes and other cover crops or fast growing trees are planted between rubber rows to control *Imperata* weed. The system aims at reducing investment cost by limiting herbicide application.

There are some differences in technology and management between the three systems (jungle rubber, RAS and the monocultural system). RAS requires low to medium input levels but can promote and diversify farm income through the use of clonal rubber and related perennial crops such as timber, fruits, pulp trees and rattan (e.g. *Calamus* sp.). A summary of the differentiation between the three rubber management systems can be seen in Table 2.4.

Table 2.4 Summary of the differentiation between jungle rubber, the Rubber Agroforestry System (RAS) and the monocultural system

	Jungle rubber	**Rubber Agroforestry System (RAS)**	**Monocultural Rubber**
Land preparation	Extensive slash and burn for upland paddy	Extensive slash and burn; paddy field	Intensive, slash and burn, mechanised
Seedlings	Unselected ; collected from “jungle” rubber	Clonal (high yield varieties)	Clonal (High yield varieties)
	No planting distance/ irregular, up to 1000 trees/ha	Some regular (3 x 6 metres) and irregular, planting densities average 550 trees	All regular (3x6 m), planting densities are 550 trees
Weeding	No weeding or only once a year, mostly let grow as secondary forest for 8-10 years until tapping time	Limited weeding, keeping secondary vegetation regenerated	Intensive and regular weeding (4 - 6 times a year)
Fertilizing	No fertilizing	Fertilizing periodically; chemical or manure	Application of chemical fertilizer periodically
Pest and diseases	No treatment	Regular prevention and treatment (Pesticides and fungicides)	Regular prevention and treatment (Pesticides and fungicides)
Other trees in the rubber plantation	Planted or naturally growing Trees and fruits : Durian (*Durio zibhetinus*); (*Aquilaria malacensis*), etc	Planted other trees (timber and fruits) in between rubber trees with space arrangement	Rubber only
Yield	Latex, food, fruits, fodder, fuel wood and timber	Latex, timber and fruits	Latex only
Start production	10 years	6 years	5-6 years
Tapping system	Very intense	Tapping on regular schedule	Tapping on regular schedule
Labour/work hour	Low	Medium	High
Input	Low input	Medium	High input
Yield/Latex Production	Relatively low, about 400 to 600 kg/ha/year of dry rubber	Medium,	high, 1000 to 1800 kg/ha/year
Environmental function	Intangible benefits; soil conservation, protection of water quality, carbon sequestration	Limited intangible benefits conservation, protection of water quality, carbon sequestration	Less environmental function
Biodiversity	High/rich	Medium	Poor

Sources : (Gouyon et al., 1993; Joshi et al., 2003; Joshi et al., 2009; Michon and de Foresta, 1995b; Penot, 1996; Suyanto et al., 2005) and field observation.

From the comparison in Table 2.4, it can be seen that the position of RAS is in the middle between jungle rubber (the traditional system) and the monocultural system. RAS can accommodate the sustainability of the jungle rubber format in conserving the environmental function of jungle rubber in keeping trees and biodiversities, but on the other hand RAS also accommodates the main high production of latex by introducing clonal rubber. This combination may keep the balance in the environmental and social function of the forest as well as production. RAS can be used as a bridge for farmers who have limited access to capital to increase their productivity gradually until they become close to the monocultural system's productivity (Joshi, 2008, pers. com)[1].

The main difference between jungle rubber and the other two systems, and the key to the higher level of rubber productivity is the use of clonal rubber (Joshi et al., 2002). It is therefore important to select rubber clones that produce a high latex yield and have the desired properties when planting the rubber tree (Ong, 2000). Clonal rubber is referred to as "budded" clones and mother trees are reproduced by budding to get seedlings with identical qualities to those of the mother tree (Delabare and Serier, 2000).

Clonal rubber is not only distinguished by its high latex yield but also has other superior qualities such as resistance to wind and to disease, adaptability to poor soil conditions, bark thickness and consistency and capacity for renewal after tapping (Delabare and Serier, 2000). Indonesian Rubber Research Institute (IRRI) in Sembawa Research Station has carried out extensive experiments and produced a series of superior clonal rubbers (RRIM 600, RRIM 712, BPM 1, BPM 109, PB 260, RRIC 100) (Anwar, 2006). The RAS projects used the recommended clones from IRRI for the Sumatra and Kalimantan regions including PB 260, RRIC 100, BPM 1 and RRIM 600 in demonstration plots (Joshi et al., 2002). These clones were chosen as they are high yielding, fast growing, and predicted to be suitable for field conditions in these areas, have a tolerance to a hard tapping system and are also resistant to leaf disease (Joshi et al., 2002).

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[1]. Joshi is a senior ethno-ecologist at ICRAF and researcher in Rubber Agroforestry System (RAS) who also was my 3rd PhD supervisor

The following are some basic activities carried out in the RAS project:

1. *Establishment of Demonstration Plots*

Demonstration plots of RAS (on-farm trials) were established on rubber farmers' land in order to develop and test clonal rubber under traditional practice. These demonstration plots functioned for the study of clonal rubber growth and production in an environment similar to the traditional system of jungle rubber. For the researchers the demonstration plots functioned as farm trials to test for the suitability of clonal rubber in local agro-ecological conditions, labour and cost requirements, and to determine the optimum level of intensification. For the farmers, this was a useful way to increase their awareness and knowledge of and motivation for non-project farmers to adopt the recommended technology.

The demonstration plots were set up with the participation of around 100 farmers in three selected provinces: Jambi, West Sumatra and West Kalimantan. The demonstration areas varied between 0.5 hectares and 2 hectares. To establish demonstration plots, the researchers and field staff from ICRAF visited rubber farmers in the villages, bringing the concept of the RAS project. The implementation of RAS used a participatory approach to conduct on-farm trials, through meetings of researcher, village leaders and farmers. The meetings were held in each village to identify appropriate farmers and locations for on-farm trials. Biophysical and social characteristics were used as a basis for choosing farmers' participation in these trials (Williams et al., 2001). In the meetings the staff from ICRAF discovered the farmers who were keen and interested in planting clonal rubber and had motivation and commitment to the project. The other criterion consisted of farmers who had cleared secondary forest or old rubber and had planned to plant rubber. The farmers also had a location with good accessibility, such as being close to the road as the demonstration needed to be in the easiest and most convenient situation in order to be observed by the farmers. The minimum size for the demonstration plot was 0.5 hectares; the farmers had to agree to it and have the ability to establish fences around their land. After the potential farmers were found, the land was inspected by project researchers before it was chosen for the establishment of demonstration plots.

Those farmers who joined the project received incentives and assistance such as free clonal rubber, fertiliser, fungicide, pesticides and technical advice. They were responsible for clearing the field, building a fence, planting and fertilising the trees, implementing the weeding treatments, and other treatments based on the procedures offered by the project (Williams, 2000; Williams et al., 2001). For each project there were two or three field assistants from ICRAF and extension workers from the local government. The location of the demonstration plots in study area in Jambi and West Kalimantan are summarised in Table 2.5.

Table 2.5 Location of demonstration plots in Jambi and West Kalimantan

Locations/ Villages	Number of plots	Total Size plot (ha)	Clonal rubber
Jambi			
Rantau Pandan	9	4.5	PB 260, RRIC 100, RRIM 600, BPM 1, GT1
Lubuk Kayu Aro	1	1	PB 260,
Sepunggur	9	4.5	PB 260
Pulau Temiang	3	1.5	PB 260
West Kalimantan			
Embaong	10	5.6	PB 260, RRIC 100, BPM 1, RRIM 600
Pana	10	5	PB 260
Kopar	10	6.4	PB260,RRIC100,BPM1
Senunuk	5	2.5	PB260

Source: (ICRAF, 2005)

There were different approaches to the establishment of demonstration plots in Jambi and West Kalimantan. In Jambi the establishment of demonstration plots was carried out by individual farmers helped by their family members. The due date and schedule of activities were agreed between farmers and researcher. The researchers and the field staff visited farmers regularly, especially for particular steps such as planting, weeding and fertilising. The researchers also visited the farmers if they needed assistance and there was a regular visit to measure the data of rubber growth. Regular meetings were more personal between researcher and farmer and rarely did meetings happen in groups.

Meanwhile in West Kalimantan, field staff used farmers' group activities to establish and maintain the demonstration plots. All participant farmers were in a farmers' group and each member in the farmers' group helped others to establish clonal rubber on their land. Work schedules were set up together and field staff from ICRAF accompanied farmers in every activity. This system helped them to set up the demonstration plots on time as they shared their labour. ICRAF staff had more opportunity to communicate and to transfer technical knowledge to farmers in a group. Regular informal meetings in the field took place to assist rubber farmers in the application and maintenance of planting clonal rubber. In addition, without supervision from field staff, the farmers were also encouraged to have their own meetings and work together to share their knowledge with other farmers. The farmers who had technical knowledge were encouraged to create another farmers' group with non participant farmers as members to transfer their knowledge.

2. *Training and Nursery program*

Training was important for increasing the technical knowledge of rubber farmers in the management of clonal rubber. The training covered various topics such as rubber nursery techniques and management, bud grafting techniques, cultivation and land preparation, planting, weeding and fertilising, tapping technique, disease control, rubber processing and the rubber business. The training was organized by ICRAF in collaboration with the Indonesian Rubber Research Institute and extension services from local districts, both in Jambi and West Kalimantan.

The training included formal classes, practical group dynamics and field study, especially for participant farmers with demonstration plots. Theoretical courses were held in the class, followed by practice in the field in the technique that was needed for planting clonal rubber and such preparation as budwood grafting in rubber seedlings. The training was designed to be intensive, interactive and group-based using a practical learning process. Farmers made field visits to the ICRAF research site and to other farmers who were successful in the development of clonal rubber. The field visits allowed farmers to study clonal rubber and to enhance their confidence before applying it to their own land. By training and field visits, participant farmers were encouraged to spread their information and knowledge to other non participant farmers as the diffusion of clonal rubber depends on farmer to farmer interactions.

Training in grafting technology in order to provide material for the planting of clonal seedlings was also held in Jambi and West Kalimantan. To accelerate the spread of technology, training on grafting techniques was organized for the farmers' groups followed by a nursery programme for the production and dissemination of clonal rubber planting material to farmers. These nurseries aimed to support the availability of clonal rubber of good quality and reasonable price, and to support farmers to produce their own clonal rubber. In West Kalimantan, budwood nurseries to produce clonal seedlings for farmers were established in 1995 and 2005. In Jambi, the nursery program emphasized a root stock and budwood nursery for farmers' groups and private nurseries.

Farmers' groups were established with assistance from ICRAF field officers in Jambi and West Kalimantan. Each group consisted of 12-15 members and they were trained in the basic knowledge of grafting until they were ready to plant clonal seedlings. To maintain the programs, meetings were held frequently and were usually attended also by government extension officers. All the farmers with a basic knowledge of grafting techniques in groups were encouraged and assisted to set up their own group nurseries and plant clonal stocks to fulfil their need for seedlings. As a group they worked together on routine nursery activities such as seeding, transplanting, watering and weeding until the seedlings were ready to be planted on the farmer's land.

2.7 Problems in the Adoption of New Technologies

As mentioned in earlier parts of this chapter, there have been various projects in smallholding rubber carried out by the Indonesian government and other agencies since the 1970s, to increase rubber production as well as the livelihoods and income of rubber farmers. The production of rubber in Indonesia has tended to increase, but mostly because of the development of new rubber areas rather than increased rubber productivity. The prospect of increasing rubber production by increasing of the area in Indonesia faces more uncertainties. Increased population and conversion of forest land to other purposes such as oil palm plantation has limited the availability of land for rubber. Application of various technologies is needed to increase rubber productivity and these have been introduced by governments and various organisations. However the adoption of clonal rubber technologies by smallholder farmers has been slow. Smallholder rubber which mostly uses unselected seedlings still has lower productivity compared to that of smallholder farmers in other countries, or the rubber productivity of private and government estates in Indonesia itself.

The use of clonal rubber shows its ability to increase the latex productivity of rubber in Indonesia. In the case of the RAS programme, in the demonstration plots, clonal rubber PB 260 and RRIC 100 were the best in terms of girth growth and all tested clones had a faster growth rate than unselected rubber seedlings (Joshi et al 2002). However, only a minority of smallholders actually used and adopted the recommended rubber technologies (Gouyon and Nancy, 1989; Supriadi and Chamala, 1992) using their traditional system (extensive jungle rubber) (van Noordwijk et al., 2004) and only about 18% of smallholders managed their rubber gardens intensively as monocultural plantations (IRRI, & ICRAF , 2006). From the total of 502,642 ha of rubber plantations in Jambi in 1993, only 3,447 ha of smallholders used improved high yield seedlings under intensive management (Murdiyarso et al., 2002). Even though rubber has been planted by smallholders since early this century, rubber smallholdings' productivity is generally far behind the larger estates in yield, productivity, and quality (Supriadi and Chamala, 1998).

In developing countries such as Indonesia which are characterised by small, complex, diverse, resource-limited farming communities, it is common for farmers not to adopt new technologies. Many technological packages developed and proposed by the Government or other organisations have technically failed when transferred from research station to farmers' fields. In many cases, researchers are unsuccessful in understanding farmers' constraints and opportunities prior to developing technological solutions to farmers' problems. In the case of clonal rubber, adoption of clonal rubber to increase productivity still needs to be increased. Therefore this thesis attempts to understand, especially from the farmers' point of view, the reasons they do or do not adopt clonal rubber, in order to provide the necessary interventions to increase adoption.

2.8 Summary

Indonesia has an important position in the world as a rubber producer, with the largest rubber area and it is the second biggest rubber production after Thailand. The national economic and social contribution of rubber is very important, as well as providing job opportunities for millions of people especially in rural areas. Rubber was introduced to Indonesia in the early 20th century and spread to several provinces and was adapted to the traditional rubber system called jungle rubber. This rubber system has made a significant contribution, providing other non rubber products for the livelihood of people as well as helping the environment. However, it has low productivity compared to the monocultural intensive system of private and government estates. Since the 1970s the Indonesian government has collaborated with other agencies and introduced programmes aimed to increase the productivity of smallholder rubber as well as rubber farmers' incomes; however these projects have covered only small numbers and the adoption of improved technology by smallholder farmers remains low. The reasons behind this lower adoption are still unclear and vary by location, project and method of diffusion. This thesis aims to answer the question of why some rubber farmers in two locations, Jambi and West Kalimantan adopt and others do not adopt clonal rubber.

There are many factors that can influence farmers' decisions, and it is important to understand and consider them in learning farmers' perceptions, needs and limitations. This leads to the next chapter; the factors affecting the adoption of agroforestry and the decision making system of farmers regarding the adoption of new agroforestry technologies. Factors, decision theories and the associated analytical methods are presented in Chapter 3.

Chapter 3 Decision Making in the Adoption of Agroforestry Technologies

3.1 Introduction

This chapter will cover a review of relevant literature on the concept of adoption of agroforestry technologies. The literature review of decision theories and decision making models is also provided. In this chapter, the theoretical framework of quantitative and qualitative research as well as combination models to analyze the adoption of new technologies will be reviewed. Then, I will conclude by discussing the way the theory of diffusion of new technology and a combination of decision making models fit the study.

3.2 The Adoption of New Technology in Agroforestry

3.2.1 Agroforestry Technology

Agroforestry is a combination of two main components, agriculture and forestry, therefore agroforestry technologies are the practice of utilizing both forestry and agricultural technologies. Agroforestry technologies often seek to be as an innovation or improvement through scientific intervention to either modify an existing system or develop a new one (Nair, 1993). These technologies may involve new species, improved and high yield seedlings, introduction of trees into the agricultural landscape or intensified management practices to the traditional system. Agroforestry technologies can be varied and be specified depending on the problem in the field. Different types of technologies deal with specific farmers' need, environmental requirements, space and time (Sanchez, 1995). These technologies are usually to solve the problems that are faced by farmers in order to maximize land productivity. For example, a low soil fertility problem could be addressed by the introduction of various new technologies such as a tree fertilizer system, livestock or green manure. To increase farmers' income a combination of high value trees, agricultural and silvopasture could be applied. For example for solving fuel wood problems in Africa, agroforestry technologies of rotational woodlots were introduced to farmers (Ajayi et al., 2006). In this study, the Rubber Agroforestry System including clonal rubber has been introduced to rubber farmers to enhance their rubber production.

The agroforestry technologies include innovation or improvement and have specific characteristics that are different from existing agricultural and agroforestry practices (Nair, 1993). An agroforestry system is characterized by a combination of trees and agricultural crops and/or animals in the same area of land management. Therefore agroforestry is more complex than traditional agriculture as it is more multi-component and multiproduct and also has some characteristics related to the variety of economic, social and ecological processes involved (Mercer, 2004; Sanchez, 1995). This complexity can have an effect as it requires more input such as capital and labour. In addition as a complex system of interactions of agroforestry components, it has to be managed for multiple alternatives and social interests. Thus agroforestry technologies are typically more knowledge-intensive and have more complex management requirements than conventional agricultural development (Franzel and Scherr, 2002; Meyer, 2004).

Agroforestry technologies are also characterised by longer periods of testing and achieving a result compared to agricultural technologies. Therefore there is a waiting period where farmers have to wait for three to six years before obtaining benefits (Franzel and Scherr, 2002). In the case of rubber it can take 5-6 years from planting to harvesting latex.

As the agroforestry technologies are the results of improvement through scientific intervention these practices need to be disseminated to farmers via various activities such as training and demonstration plots. The diffusion stage of these new technologies to farmers has an important role in the adoption process and is one of the keys of successful adoption by farmers. To understand the diffusion and adoption of new technologies, Rogers' diffusion of innovation theory is widely used.

3.2.2 Agroforestry Technology Diffusion

The adoption-diffusion of innovation model proposed by Rogers has provided a popular framework to explain how new technologies are diffused and adopted (Rogers, 2003). This concept is also applicable in the agroforestry science (Baig et al., 2005). Rogers (2003, p.5) defined diffusion as "*the process by which an innovation is communicated through certain channels over time among the members of a social system"*. Based on this definition he further identified four main elements of diffusion of new technologies including:

1 The characteristics of new technologies

Agroforestry technology characteristics have an important role in the rate of adoption. The interrelated technologies' attributes including relative advantage, compatibility, complexity, trialability and observability have an influence on the farmers decision to adopt new technologies (Rogers, 2003).

2 Communication channels

The second element is communication channel. The new technologies should be communicated to potential adopters through communication channels. Communication is defined as "*a process in which participants create and share information with one another to reach a mutual understanding*" (Rogers, 2003, p.5) . In diffusion theory, the communication process involves an innovation, a "components" of adoption (individual or organization) that is familiar with the new technology and has applied it, other "units" of adoption who have not yet practised the technology, and a channel of communicating between the two components.

There are two general categories of communication, individual and mass media. The individual channel is the process by which messages get from one farmer to another involving one-on-one communication between people. Individual or interpersonal channels are probably the most commonly used extension methods in both developed and developing countries. Meanwhile, mass media are those channels of communication which can spread the information and knowledge to large numbers of people at the same time. Mass communication through media channels such as radio, television and newspaper is more effective in spreading knowledge of the new technologies (Oakley and Garforth, 1985). In Rogers' diffusion of innovation theory, there is an important correlation between the source of communication about the innovation and the rate of adoption. Communication has an important role to form and change the attitude of potential adopters and to influence the decision to adopt or not to adopt new technologies Rogers (2003). Rogers also mentioned the important role of opinion leaders and the role of agents of change. More discussion on information exchange as part of training and extension is in part 3.3.3 of this chapter.

3 The time period

The third element involved in diffusion adoption is the time dimension. Time in this theory is involved in (1) the innovation-diffusion process, (2) innovativeness, and (3) an innovation's rate of adoption. In the innovation-diffusion process Rogers conceptualises five steps namely knowledge, persuasion, decision, implementation and confirmation. These steps are further discussed in part 3.2.3. The time is also involved in the level of adoption as the time taken to adopt new technologies or innovativeness. Rogers defined innovativeness as the degree to which an individual is relatively early in adopting new ideas compared to other members of a system. Based on the farmer's innovativeness, he categorised five adopters namely innovator, early adopter, early majority, late majority and laggards.

Innovators are described as potential adopters who are eager to accept new technologies. They are characterised as having more years formal education, larger farms, contacts with change agents and with other innovators, cosmopolitan social relationships, access to mass media channels, and an ability to understand and apply complex technical knowledge. They also have sufficient financial resources to cope well with uncertainty. The innovators have an important role in transferring the new technologies from outside the system (Rogers, 2003).

The next category is early adopters, the farmers who are more careful and want to see the idea tried and proved under their local conditions. These farmers are more integrated to the local social system than cosmopolites. They become role models for other farmers as they are selective and careful in making decisions about new practice, they reduce uncertainty by adopting it and they have connection with change agents.

The next category is early majority. Rogers characterised this category as the people who adopt new technologies before the average member of a system and their position is in between early adopters and the relatively late adopters making them important as a link in the diffusion process (Rogers, 2003).

Innovators and early adopters are indicated as having higher socio-economic status than later adopters (Rogers, 2003). Meanwhile late adopters are described as sceptical, they adopt new ideas just after the average member of a social system, they have more limited resources, are sceptical out of financial necessity or as a response to network pressures, are more traditional and risk avoiding, less wealthy and of lower social status.

Laggards as the last adopter category are described as having strong traditional values, isolated in their social system, strong connection to the past, uncertain about innovation and lower financial status. The late adopters take a much longer time than early adopters to adopt new technologies and laggards are described as resistant to new technologies. Rogers highlighted that laggards should not be perceived negatively. However, the category of ‘laggard’ as the last group in a social system to adopt new technology has been criticized as an unnecessary categorisation for the non adopter/late adopters (Sapp, 2011, Pannell et al., 2006; Klein, 2005, Wilson et al., 2000). Not all laggards are ignorant or resistant to change, but those non-adopters have rational reasons why do they not adopt new technologies from their own perspective (Sapp, 2011, Vanclay, 2002). Individual farmers take into account their exceptional situation such as their land, financial ability, their values and their own goals in their decision not adopt new technologies. Klein (2005) found that laggards were not resistant to new technology but they have their own reasons such as they believed that they would not be able to afford it, the new technology is relatively expensive compared to its benefits, the technology is probably not fit for them, or diffusion of technology was mediated by those who have an interest such as the Government. In addition, Cramb (2000) highlighted that both the objectives, livelihood strategies and the available resources vary between farmers and thus farmers in the same environment may respond differently to a given technology.

In agroforestry studies, time is very important as a long time period is needed for new agroforestry technologies to spread and be adopted by farmers. In addition agroforestry is characterised by a waiting period to get the result of new technologies. Therefore time is a crucial factor. The farmer as a potential adopter also takes many years for testing and adopting the new technologies (Ajayi et al., 2006). The waiting period could give an opportunity for the farmers to learn and to experiment before making a decision for adoption (Vosti et al., 1997). Further, by learning and experimenting, uncertainty is reduced through time and experience, and when their confidence has been raised then they may adopt the technologies (Feder and Umali, 1993). However longer time until self sustainability and the complication of the process also cause slower adoption by some farmers (Amacher et al., 2004), especially for farmers who have limited land or have no alternative job to support their life during the waiting period.

As adoption takes a long time, some authors add categories as they found farmers could change their decision in the process of adoption. Adopter category is distinguished between testers, experimenters and adopters (Adesina et al., 2000; Franzel and Scherr, 2002) and non adopters are also recognised as genuine testers/rejecters, pseudo-adopters and re-adopters (Kiptot et al., 2007). The pseudo-adopters are defined as the farmers who tried improved tree fallow with different objectives. These included benefit from project activities and incentives such as getting free inputs, participating in training which often involved payment, access to credit and market and gaining prestige (Kiptot et al., 2007). However, this study will emphasize the main reasons behind the decision to or not adopt the new technology. Rogers' theory combined with other scholars' studies can be used as direction to study adopters and non adopters based on their social economic conditions and their main reasons and constraints.

4 The social system

The fourth main element in the diffusion of new technologies is the social system. The social system can be defined "*as a set of interrelated units that are engaged in joint problem solving to accomplish a common goal"* (Rogers, 2003, p.23) . All diffusion occurs within a social system, whose members may be individuals, informal groups, organizations, or subsystems, but who share a common goal or objective that links them together as a social system (Dearing, 2009; Rogers, 2003).

Diffusion occurs within a social system, therefore the social structure of the system influences the diffusion of technologies. The social structure can be defined *as the patterned arrangements of the units in the system, which gives stability and regularity to individual behaviour in the system* (p.37). These social structures such as the nature of the social system, norms, role and opinions of leader, change agents, communication network/system, type of innovation decision and the consequences of new technologies may influence farmers' decisions. As the new technologies should be compatible to the social system, this theory will be useful in order to study the effect of social structure on adoption as in the two main study locations there were differences in religions cultures and norms (Rogers, 2003). The social system is also important to studying whether the economics of agroforestry are more important than social factors in slowing adoption. The agroforestry is linked to social problems such as lack of labour. Members of a social system such as family, opinion leaders, and change agents are the people who have the ability to influence the diffusion of innovation within a social system (Rogers, 1995). More discussion about the influence of social system to the adoption is in part of 3.3.4.

3.2.3 Agroforestry Technology Adoption

Following Rogers' concept of diffusion of innovation (Rogers, 2003, p.21) adoption can be defined as "*a decision to make full use of new technologies as the best course of action available and rejection as a decision not to adopt new technologies"*. As agroforestry is characterised by longer time in process and adoption the other definition proposed by Feder et al. (1985) will be useful. They defined adoption as "*the degree of use of a new technology in the long-run equilibrium when the farmer has full information about the new technology and its potential"* (Feder et al., 1985, p.256). The adoption of technologies is a process that takes time from introduction to complete adoption. Rogers (2003, p.20) defines the adoption process as "*the mental process an individual passes from first hearing about an innovation to final adoption*". As a mental process, adoption of new technologies is not an instantaneous act; it is a process that occurs over time and consists of a series of different actions (Rogers, 2003) and these stages are not as simple as a single decision to adopt or do not adopt new technologies (Hornik, 2004).

The innovation–decision process is the process that an individual as decision maker passes through in five stages namely: Awareness of knowledge of an innovation, attitude towards the innovation, decision to adopt or to reject, implementation, and finally the confirmation of the decision (Rogers, 2003).

1 *Awareness of Knowledge*. In the first stage the farmers become aware of a new technology and gain knowledge by learning it so they have an idea of how the technology works and understand how it functions as well as its benefits for them. In this process the farmer is looking for information about new technology especially in order to reduce the uncertainty of the disadvantages and consequences from the adoption of new technology (Haider, 2004; Hornik, 2004). In this stage Haider

(2004, p. 164-168) mentioned that the awareness of knowledge relates to the process of familiarizing oneself (cognitive process) with an innovation (awareness knowledge), how to use it (how-to knowledge), and what the innovation is for (principles knowledge).

2 *Persuasion.* Farmers have positive or negative thoughts toward the new technologies. The persuasion stage (Haider 2004 p. 169-172) is the psychological process where the decision maker actively searches for more information about the innovation. The focus is on finding reliable sources of information, a sufficient quantity and quality of information and the strategy to construe the information. The benefits and costs of an innovation are evaluated and some social justifications are sought for developing her/his (negative or positive) perceptions of the innovation.

3 *Decision choice*. After the stage of persuasion then farmers as the decision makers take an action to make a small-scale trial or observe the trials performed by their peers. Based on this trial or observation there is a choice to adopt or to not adopt the new technologies.

4 *Implementation.* This is the stage when the farmer as decision maker also looks for more information on the new technologies and the application procedures and then applies the new technologies to the farming practice on their land. Decision makers may realise that there are uncertainties, then they cope with these by different strategies such as modifying the procedures or the technology itself, or adopting part of the new technologies.

5 *Confirmation.* At this point, farmers evaluate the result of their implementation of new technologies, evaluate the results of the decision already made and based on that confirmation either they decide to choose the best action to use new technologies in full, part of them or to choose not to adopt (reject) the new technologies.

The model of Rogers' adoption of innovation is useful for understanding farmers' decision making processes of adopting new technologies including the case of new agroforestry technologies' adoption (Baig et al., 2005; Mercer, 2004; Raintree, 1983). However this model does not mention in detail how to access the decision process in individual decision makers. For this reason, approaches from Gladwin (1989a) may complement and add more detail in the decision process. Gladwin proposed the Ethnographic Decision Tree Model (EDTM) (more detail is in part 3.4.2) to access the decision making process of farmers in adoption of new technologies. In the process Gladwin (1980, 1989) explains that the decision maker follows two main stages of the process in their decision to choose from particular options. The two main stages are:

1 *Stage of Pre-attentive or the unconscious decision process*. In this stage, when decision makers face a number of alternatives, they will eliminate rapidly or pre-attentively all alternatives which have some unwanted aspects (Gladwin, 1980; Gladwin, 1989b; Murtaugh and Gladwin, 1980). For example, farmers do not want to choose planting potatoes if there is no availability of planting materials or will not plant vegetables if there is no irrigation (Jangu, 1997). After farmers have selected an option, they will continue to stage 2.

2 *Stage of maximisation subject to constraints*. In this stage, farmers face a smaller number of selected options as a result of stage 1, and it is in this stage that farmers make the real decision. In stage 2 there are six steps namely: listing of aspects, elimination of aspects, selection of aspects, constraints, passing through constraints and alternative strategies. During this stage decision makers consciously choose from the options, ordering them on one aspect or decision criterion, and then pass the options ordered through a set of constraints (Gladwin et al., 2002a). If the option passes all the constraints, it is adopted, but if not the other options get a chance to pass the constraints.

Gladwin (1980) represented this process in the simple format of a tree in which the structure of the tree will be dependent on the number of alternatives, aspects and constraints. More about the decision tree will be explained in part 3.3.2.

Table 3.1 Decision process in adoption based on Rogers (2003) and Gladwin (1989)

	Decision Making Process in Adoption	
	Rogers (2003)	Gladwin (1989)
1	Awareness of Knowledge	Pre-attentive or unconscious process
2	Persuasion	
3	Decision choice	Maximisation subject to constraints:
		1. Listing of aspects
		2. Elimination of aspect
		3. Selection of aspects (subjective worth and ordering alternatives)
		4. Constraints
		5. Passing through constraints
		6. Alternatives strategies
4	Implementation	
5	Confirmation	

The first of Gladwin's (1980) stages and approaches to the decision making process matches and complements the first two stages in the diffusion of innovation model of Rogers (1983). In this first process "awareness of knowledge" decision makers (farmers) gathered information related to the new technologies including the process of familiarizing (cognitive process) of an innovation, how to use it (how-to knowledge) what the innovation is for (principles knowledge). In the second process "persuasion" in finding information on the benefits and costs of an innovation and social justifications to develop their perception is complemented by the first stage of Gladwin. In this stage farmers limited the choices as they were informed of unwanted aspects.

In Roger's theory, after the second stage of persuasion the farmer is then directed to move to options in the last three stages namely decision, implementation and confirmation. These stages correspond to stage 2 of Gladwin's maximisation subject to constraints. Gladwin mentioned that after passing the stage 1 process, farmers then proceed to the real decision process as maximisation subject to constraints. In this stage, farmers face fewer selected options as a result of stage 1, and in this stage farmers make real decisions. In Gladwin's stages farmers as decision makers make a listing of the options that are available to them, and then select the choices. They formulate the constraints and pass the alternative through constraints. If they pass the constraints they consider adopting the alternative.

In addition, usually agroforestry technologies have been introduced to the farmers in a package that has different components such as technical training, incentives, seedlings, fertilizing and a harvesting system. Some components of technology in the package may complement each other and some of them can be adopted independently (Feder et.al, 1985). Sometimes some conditions made them impossible to adopt and they become partially adopted. For example, farmers use clonal rubber but they do not fertilise, as their capital is only sufficient to buy clonal rubber.

The innovation-diffusion model that was introduced by Rogers (2003) has been seen as applicable to farm forestry participation (Burch, 1986; Caveness, 1991). Also some studies in forestry used Rogers' theory as a conceptual framework (Glendinning et al., 2001; Wejnert, 2002). Furthermore, this study adopts the concepts of Rogers but is also linked to studies carried out by other researchers on the adoption of new technologies in agriculture, forestry and agroforestry in Indonesia and other developing countries (Ajayi et al., 2006; Gladwin, 1989b; Gladwin et al., 2002a; Sambodo, 2007; Wurjanto, 2001).

3.3 Factors Influencing Adoption

Many studies have been undertaken by researchers on the adoption of new technologies in agriculture by smallholder farmers. Accordingly, in the literature there has been investigation of the decision-making process and factors that influence the adoption of new technologies. These factors may include the individuals' personality, socio-demographic characteristics, networks, and prior knowledge of the topic. In many recent works, the impact of factors such as credit, information availability, risk, and farm size on farmer adoption behaviour also has been investigated (Feder and Umali, 1993). However, the model has been difficult to generalise as adoption is very specific to the different characteristics and backgrounds of farmers, the characteristics of the technology and diffusion methods. Similarly to any new technology adoption, agroforestry technology adoption is a complicated process that may be influenced by many factors (Ajayi et al., 2003b; Kiptot et al., 2007; Mercer, 2004). It is difficult to find separate factors that influence the decision to adopt new technologies as there is correlation and interaction between factors. However, to make it easier, each factor will be explained as a single factor with some correlation to other studies.

Factors influencing the adoption of new technologies are mentioned in many literatures. Rogers (2003) in his theory of diffusion of innovation mentioned some factors influencing the rate of adoption of innovation as the type of innovation-decision, the nature of communication channels, the nature of the social system and the extent of the change agent's efforts. Diffusion of innovation research can provide information, for example, on barriers and motivations and external factors that may have strong influences on the decision to adopt new technologies. In addition, based on their review, Feder et al. (1985) concluded that the adoption of agricultural technologies was influenced by such factors as; farm size, costs, risk preferences, human capital, credit constraints, labour requirements and tenure. Furthermore, in recent reviews specifically on agroforestry adoption, there were such mentioned determinants of adoption as; household preferences, resource endowments, market incentives, biophysical conditions, methodological issues (Mercer, 2004), risk and uncertainty (Kiptot et al., 2007; Mercer, 2004; Mercer and Pattanayak, 2003) and institutional and political factors (Kiptot et al., 2007). From these various studies, the factors influencing adoption that may relate to this study have been summarised in Table 3.2. In the next section the factors influencing the adoption of agroforestry technologies will be discussed in detail.

Table 3.2 Summary of the factors affecting adoption of new technology in Agroforestry

	Categorisation		Factors
1	Economic	1	Capital (land and cash)
		2	Expected profit increase
		3	Risk and uncertainty
2.	Managerial	4	Farmers' objective
		5	Labour
3	Technical	6	Technology characteristics (Relative advantage, compatibility, complexity, reliability, observability)
		7	Information Exchange
		8	Farmers Knowledge
		9	Training & Extension
		10	Demonstration plot
4	Social structure	11	Farmers group
5	Policy & Institution	12	Incentives and access to credit
		13	Infrastructure; access to clonal seedling
6	Farm and household preferences	14	Farm size
		15	Household income (off farm & on farm)
		16	Family size and Family Labour
		17	Education
		18	Age and Experience

Sources : (Doss, 2006; Feder and Umali, 1993; Feder et al., 1985; Mercer, 2004; Pattanayak et al., 2003; Rogers, 2003; Wejnert, 2002)

3.3.1 Economic

Economic factors are one of the important determinants of adoption (Pannell, 1997). Most of the economic factors mentioned in the literature are perceptions of expected profit increase, perception of risk and attitude to risk, credit options, capital, tenure and economic incentives (Feder et al., 1985; Abadi Ghadim et al., 1999; Supriadi and Chamala, 1998).

1 *Capital (Land and cash)*

In their review of the adoption of agricultural technologies in developing countries Feder and Umali (1993) mentioned that land size factor is important in the adoption of new technology. In addition population increases may lead to land use intensification, by inducing technical and institutional innovation (Scherr, 1995).

Another economic factor determining adoption is availability of capital. Capital in the form of accumulated savings or access to capital markets is crucial to pay for the cost of new technologies (Feder et al., 1985). When the farmers want to adopt new technologies, they need capital to change from their existing farming to new methods. Thus, differences in availability and access to capital is often mentioned as a major obstacle in technology adoption (Feder et al., 1985).

A study of the adoption of new technologies by rubber smallholder farmers in Malaysia by Sail & Muhammad (1994) showed that the reason for farmers not adopting new technologies was mainly financial constraints. According to this study, smallholder farmers could not afford a technology owing to insufficient cash to purchase the inputs required as the farmers were relatively poor. This is a similar conclusion to that of the study by Supriadi and Chamala (1998) in Sumatra, Indonesia, that lack of funds was one of the basic reasons given by farmers for not adopting recommended rubber technologies. The lack of capital not only limits farmers' capability to adopt new technologies but also makes the farmers modify or substitute other practices. For example in a study in Sumatra in the application of herbicides for weeding, smallholders who faced a capital constraint applied fewer herbicides or substituted for herbicides by slashing Imperata manually (Bagnall-Oakeley et al., 1996).

2 *Expected profit increase*

The expected profit increase of new technology has a significant influence on the adoption (Baig et al., 2005). The variable perceived profitability was found to have a significant influence on the adoption of agroforestry by smallholder farmers in

Taliparamba, India (Rajasekharan and Veeraputhran, 2002). Mercer and Pattanayak (2003) stated that in an empirical study, variables of expected yield increases and more income from farming positively influenced the adoption of agroforestry. A positive perception is built from the quality of information available such as demonstrating the profitability of new practices to the farmers (Rajasekharan and Veeraputhran, 2002). This indicates that new practices may not encourage adoption unless there is increased productivity and profitability (Amsalu and de Graaff, 2007). Furthermore it is reasonable to expect that the more economically beneficial the new technologies are, the higher the rate of adoption (Vanclay, 2004). According to Baerenklau and Knapp (2007), farmers will adopt a new technology if they think it is profitable and if their peers accept it. Gladwin (1979) showed that farmers will not adopt new technologies unless they have good reason to do so and the result of new technologies should be better compared to the existing system.

3 Risk and uncertainty

The new technologies usually bring some change to the traditional system which farmers have been familiar with for many years. From the farmers' point of view changing any new farming practice has a risk and some degree of uncertainty in the result. Risk and uncertainty are defined as reflecting the unknowns in the market and the institutional environment under which decisions are made (Pattanayak et al., 2003). New technologies can have subjective risks (the yield is more uncertain with an unfamiliar technique) and also objective risks such as weather variations, susceptibility to pests or uncertainty of the availability of important inputs (Feder and O'Mara, 1981). Smallholder farmers are generally risk averse and face constant difficulties in buffering various risks triggered by health, climatic and socioeconomic shocks (Shiferaw et al., 2009). Therefore risk, specifically the farmer's perception of riskiness, has an important influence on adoption decisions (Abadi Ghadim et al., 2005).

Increased risk is often considered as an important obstacle to adoption (Amacher et al., 2004; Abadi Ghadim et al., 1999; Nowak, 1992) and can limit the adoption of new practices as farmers do not want to take the risk of failure (Feder and O'Mara, 1981). However, uncertainty in response to new technologies usually leads the farmers to seek information (Dearing, 2009) and to learn about the performance of new practices in order to reduce uncertainty (Abadi Ghadim et al., 2005). Further, farmers are also influenced by the experience attained by early adopters, so the awareness of farmers will increase and the uncertainty will be reduced (Feder and O'Mara, 1981); therefore, there will be more possibility for adoption.

3.3.2 Managerial

1 Farmers' objectives

Farmers are more likely to adopt new technologies that are compatible with their farm and personal objectives. Households have many different objectives when decisions are made to use their resources (Place and Dewees, 1999). As Scherr (1995) emphasises, farmers have multiple objectives and they tend to achieve their objectives based on the resources available to them. Both the objectives and the available resources (such as land, labour, or capital) vary between farmers (Place and Dewees, 1999). These personal objectives are usually the needs for capital and income for the education of children and expenditure on household goods, food security, adequate cash income generation, a secure asset or resource base, social security and livelihood strategy and provisions for children's welfare (Place and Dewees, 1999; Scherr, 1995). They need to be flexible because uncertainty in the market place also means a lack of suitability for their personal objectives (Vanclay, 2004).

2 Labour

Labour availability is often mentioned as an important variable affecting farmers' decisions to adopt new practices. Labour is an important factor in agroforestry and farming practices as most of the work in the field in Indonesia and other developing countries is done manually. The new technologies usually have an influence on labour demand. Some new technologies are relatively labour saving, and others are labour using. So in adoption decisions, farmers are concerned if new practices will increase labour requirements. Further, the availability of family labour is often mentioned as one of the variables influencing the adoption of technologies (Rajasekharan and Veeraputhran, 2002) because family labour is usually a main source of farming labour in developing countries such as Indonesia. In the adoption of new technologies, labour shortages usually have a negative effect on the farmers' adoption (Feder et al., 1985). Nowak (1992) cites an increase in labour requirements as one reason that farmers do not adopt new systems.

However, the influence of labour on the adoption of new technologies has been determined as variable. The availability of labour tends to increase the adoption of new technologies (Abadi Ghadim and Pannell, 1999), as its availability reduces the labour constraints (Nkonya et al., 1997). Rajasekharan and Veeraputhran (2002) carried out a study on the adoption of agroforestry in smallholding rubber in the regions of Kerala in India and found that family labour was a dominant variable, which influenced adoption decisions with a positive correlation.

In the other case study constraints on family labour availability for agricultural operations resulted in increasing the extent of agroforestry adoption in Kerala, India (Sood, 2006). This is probably because farmers thought that agroforestry such as planting trees was less labour intensive than agriculture (Agarwal 1986; Malla 2000) and families with a shortage of family labour for agricultural work chose planting tree options for their land use to avoid high labour demands (Jones and Price, 1985). Therefore, there was increased agroforestry adoption by households with less labour available than by households with more family labour available for farming (Sood, 2006).

3.3.3 Technical

Rogers characterised new technologies with socio technical criteria including relative advantage, compatibility, complexity, trialability and observability (Rogers, 2003).

1 *Technology characteristics*

a. Relative advantage

Relative advantage is the level to which new technology is understood as being better than previous practises in terms of, for example, economic profitability, social prestige, cost efficiency and benefits, and people's satisfaction. The situation for each location, system and technology may vary. The farmers can observe how new agroforestry technologies might provide benefits that are better than those provided in the existing system.

Compatibility is the degree to which the technologies are compatible or incompatible with the existing socio-cultural values, beliefs and norms. New technologies in agroforestry will be quickly assessed and adopted by farmers in conditions where practises are compatible and flexible enough around existing values, past experiences and the needs of farmers (Baig et al., 2005).

b. Complexity

Complexity is the degree to which the new technology is perceived as relatively difficult to learn and use by the farmers. In some cases new agroforestry technology is more complex as it is multi-component and requires more input. However in other cases with improvement of the traditional concept of agroforestry, farmers have been familiar with the system. The level of complexity may influence levels of success in the adoption rate of agroforestry technology. The technologies that are less complex and easier to learn and put into practice are faster in their rates of adoption (Baig et al., 2005).

c. Trialability

Trialability is the degree that new technologies may be adopted or applied on a limited basis as an experiment before the decision is made for full adoption. This is especially in order to reduce the risk and uncertainty of adoption of the new technologies (Lamble and Seaman, 1994). Agroforestry technologies in application usually require large space and new technologies that can be tried on a small scale will usually be more rapidly adopted. Therefore agroforestry projects could be scaled down to address this concern of trialability and observability (Baig et al., 2005). Smaller scale agroforestry projects such as on-farm trials might be more appropriate for farmers in order to reduce their perception of high risk.

d. Observability

Observability relates to the degree to which farmers have had the opportunity to see the new technologies put into practice or see the results of the implemented practice. Some new practices are obviously more observable than others and therefore might be adopted by individuals more quickly. One of the characteristics of agroforestry is it requires more time to yield, meanwhile farmers need to be able to determine the advantages of the system through observation. Therefore for the agroforestry technologies the role of the researcher and extension workers are very important in providing an example in other places to convince and motivate farmers to adopt agroforestry technologies. One of the practical issues in observability is availability of demonstration plots.

2 Information exchange

The decision to adopt new technologies and innovation is considered to be an information seeking and processing activity where individuals are motivated to reduce uncertainty about the advantages and disadvantages associated with a new practice (Rogers, 1983). Knowledge and communication are viewed as playing key roles in the participation process. The lack of information regarding the economic or technical issues of the technology is often regarded as a barrier to adoption (Nowak, 1992). The lack of information may be correlated to other factors such as the extension system, availability of communication facilities and also cultural. There are different systems in different countries and areas regarding information exchange of new technologies. In India for example it is suggested that direct contact between extension workers and farmers, along with informal discussions between neighbouring farmers are key elements in the adoption of new practices (Glendinning et al., 2001). There are some sources of information available to farmers such as training, demonstration plots, neighbours, farmers' group, village leader and media communications such as newspapers, leaflets, programmes on TV and radio.

In the traditional system neighbours have an important influence on the adoption of new technologies, especially in terms of information exchange. Information gained by examining the actions and performance of neighbours, friends, and relatives who have conducted experiments with the new technologies is an important factor influencing other farmers in adoption (Feder et al., 1985) especially for farmers at the evaluation or trial stage of the new technologies (Glendinning et al., 2001). There are two ways to gather information from others, by observing other farmers' behaviour and imitating it (Katungi, 2007). This process can be called social learning as one individual is learning from another by means of observational modelling (Rogers, 2003). Rogers (2003) continued that individual farmers can learn by observing other farmers' activities. They did not need their own trial and error, as there were examples and evidence to observe and to follow. So the individual does not necessarily have to experience in order to accept information on new technology. In their simulation from the case study on the adoption of high-yielding seed varieties (HYV) in India and Thailand, Foster and Rosenzweig (1995) found that neighbours influenced farmers in their adoption of HYVs. A case study in Pakistan found that farmers relied on their neighbouring farmers when searching for information regarding new farming systems (Muhammad and Garforth, 1999). This confirms that informal social networks such as relatives, friends and groups are an important possibility for spreading new technologies (Kiptot et al., 2006) and promoting farmer-to-farmer approaches might be advantageous (Chambers et al., 1989). Baerenklau and Knapp (2007) also specifies that the neighbour effect may have more importance for smaller, less costly, and reversible decisions. According to Vanclay et al. (2003) for new technologies with uncertainty, diffusion happens throughout an interpersonal process and this process can either facilitate or delay adoption.

3 Farmers' knowledge

Many new technologies in farming are complex (Nowak 1992) and different from the original or ongoing system. Therefore in adopting these technologies, farmers need to increase their knowledge of the new practices as knowledge plays a crucial role in the adoption of new technologies such as IPM (Integrated Pest Management) practices (Samiee et al., 2009). Nowak (1992) states that one reason for farmers being unable to adopt is their inadequate managerial skills. The lack of knowledge about implementation of new practices is an important barrier to the adoption of IPM in Bangladesh (Chowdhury and Ray, 2009) and in Iran (Samiee et al., 2009). Supriadi and Chamala (1992) in a study of the adoption of new technologies by rubber farmers in Sumatra, Indonesia mentioned that one of the barriers to adoption was the fact that farmers need to master new skills and new management practices when the technologies were difficult to put into practice.

4 Training and extension

In some parts, new technologies usually are different from the traditional system; therefore they require particular new skills and knowledge. In addition, as mentioned before, one of the characteristics of agroforestry technology is it is more complicated than agricultural technology (Mercer, 2004), therefore training to transfer new knowledge and skills to the farmers is a very important factor in the adoption of new technology (Nguyen, 2001; Rogers, 2003). Training can also reduce the risk and uncertainty (Abadi Ghadim et al.,R2005; Sunding and Zilberman, 2001) and leads to better decisions regarding adoption of new technologies (Feder et al., 2004; Rogers, 2003). In addition, training as informal education becomes very important in the area where the educational level of the farmers is low (Nguyen, 2001). Although the farmers already have local knowledge about their system and its environment, training by extension agents can bring them new knowledge and information (Oakley and Garforth, 1985).

People who get trained are more likely to adopt the technologies than people who do not. For example, in his study in the Southern Philippines, Cramb (2004) found that training was the most influential factor which increased the adoption of soil conservation technology by farmers. For this reason methodologies are important in the effectiveness of training. Based on the guide of training from Food and Agriculture Organisation (FAO) for successful training, some society conditions have to be taken into account, such as age of participants (for example in many societies elderly people are treated with great respect), gender (traditionally, in rural areas, specific tasks are done either by men or women), religion and beliefs (members of religious groups have common beliefs and attitudes, certain times may be devoted to religious ceremonies) (Oakley and Garforth, 1985).

Women's participation in agricultural production in Indonesia is high and also women have an important role in farm management decisions. However opportunities for training are limited as mostly only male heads of households are invited to training sessions (FAO, 2006). Therefore the training agenda also has to assist women and integrate gender into project activities to improve their productivity and household income including the adoption of new practises.

Technically there are several methods of training that work best for farmers, such as training of farmer trainers and farmer visits (Ajayi et al., 2006). In this training the farmers are trained in theoretical understanding in the class and practical training in the field such as step by step guidance on how farmers prepare seedlings and to use appropriate techniques of using fertilisers and pesticides. Then the farmers are facilitated to visit a research centre and to visit other farmers who have been practising new technology and have started to get benefits from it. Exposure to benefits distinguished by earlier adopters allowed farmers to study and to enhance their confidence to apply it to their own land (Ajayi et al., 2006). Further, these participant farmers were encouraged to spread their information and knowledge and to train their families and other non participant farmers in their neighbourhood. Thus diffusion of technology becomes mostly through horizontal farmer-to-farmer interaction.

Follow-up training activities are more important to evaluate ongoing activities of application of training and to help reinforce information and complete the training experience (Nair et al., 1990; Nguyen, 2001) especially for the less educated farmers and for the adoption of sustainable technologies (Nguyen, 2001). Extension agents may provide advice and information to assist farmers in making decisions regarding adoption of new technologies. The extension activities can be individual, face-to-face methods or in a group (Oakley and Garforth, 1985; Rogers, 2003). In individual methods, the extension agent meets the farmer at home or on the farm and discusses issues of mutual interest, giving the farmer both information and advice. The atmosphere of the meeting is usually informal and relaxed, and the farmer is able to benefit from the agent's individual attention. Individual meetings are invaluable for building confidence between the agent and the farmer. Informal communication between researcher and farmers and between farmers and other farmers has an important role in the communication of new technologies (Isaac et al., 2007; van den Ban, 1987). The extension agents can use market days, holiday celebrations or religious events to contact the farmers. The extension agents can use traditional groups and religious groups to have contact with the farmers. Cramb (2004) found that farmer based, group training was effective in increasing technical knowledge and motivating farmers to adopt new technology in the Southern Philippines.

5 Demonstration plots

Demonstration plots are an important factor in the diffusion of new technology and can be a supporting factor in adoption (McDonald and Brown, 2000). Demonstration plots can be plots that are established on the land of farmers as participants in a project (on-farm trials), or demonstrations by the farmers who have developed clonal rubber through self motivation. The demonstration plots are established with the objective to evaluate new technologies in a real situation under real farming conditions, to help farmers become familiar with new practices (Hicks et al., 1997; Roshetko et al., 2005). On-farm trials provided key information about facts in the field for farmers to learn before adopting (Roothaert et al., 2003; Wibawa et al., 2005b) as many farmers wish to observe a new innovation over time before making a decision to adopt new technologies (Fischer et al., 1996).

Demonstrations should be carried out on farmers' land with farmers participation involved in the whole process as it will increase farmers' confidence in application of new technologies (Oakley and Garforth, 1985). Further, demonstration will give the farmers opportunity to observe by themselves with concrete results the differences between a recommended new practice and traditional practices (Oakley and Garforth, 1985).

If farmers are able to experiment with new practices at their own place it can indicate a high level of compatibility with their traditional system (Shiferaw et al., 2009). The importance of successful demonstration plots to increase positive perception and confidence of the farmers was mentioned in several studies (Gladwin, 1979; Oakley and Garforth, 1985; Pannell, 1997).

For the researcher or extension worker, an on-farm trial can be used to study and to modify new technologies related to farmers' needs and availability of resources (Wibawa et al., 2005). Also, they may learn and diagnose constraints and opportunities in developing new technologies in the field, learn from farmers' knowledge and experience with traditional systems; evaluate components of technologies and testing new technologies, as well as assess farmers' adoption and outcome of new technologies to farmers (Scherr, 1991). From this learning, the researcher and extension worker may modify new technologies and make them more appropriate to farmers' needs and conditions.

3.3.4 Social Structure

Social and cultural factors influence people in making the decision to adopt agroforestry technology. The last of the four primary elements of Rogers' diffusion of innovation theory is the social system (Rogers, 2003). In many developing countries, socio cultural factors are determinants of the adoption of new technologies (Vanclay and Lawrence, 1995). Characteristics of the social network in this study are: membership and involvement in a farmers group or participation in meetings, networks with neighbours, friends and colleagues and interaction with researcher or extension agents. Social capital is the term for the groups, networks, norms and trust that people have available to them for production purposes (Grootaert, 1999). Social cohesiveness is part of social capital including the involvement of people in working together as a community to reach production purposes.

Farmers groups have an important role in the adoption of new technologies. This can be related to other factors such as access to information, incentives and labour availability. In their study of adoption of conservation technologies in Africa, Shiferaw et al. (2009) showed that membership of a farmers' group played a significant role in the adoption of the new practices, by helping farmers deal with information about markets and the limitations of new technologies. Kiptot et al.(2006), in the case of sharing seed, found that a farmer who is a member of a group has more chance to get more information as he works with and has contact with other farmers. In the case of use of maize and cassava technologies Omobolanle (2007) found farmers who are group members get more information as there were correlations between organizational membership and extension contact. In addition the logit model developed in the study of adoption of alley farming for Cameroon (Adesina et al., 1999) showed that adoption is higher for farmers with contact with extension agencies working on agroforestry technologies and those who belong to farmers' groups.

3.3.5 Policy and Institution

1 Incentives and credit

As the lower income of smallholder farmers may limit their adoption of agroforestry technologies, incentives and credit have an important influence on adoption. Agroforestry practices with a long-run term of investment typically need incentives from the government to support the farmers (Alavalapati et al., 1995) this is also because farmers have to wait a long time from the initial planting to get a yield.

Incentives can be defined as payments of cash or in kind that are given to person or system in order to encourage behavioural change including the adoption of a new idea (Rogers, 2003). Such incentives could be in the form of financial support such as subsidies, credit or loans and in terms of services such as technical support, road, market and price supports (Alavalapati et al., 1995). These incentives have been used to speed the adoption of new technologies. These can be useful for facilitating initiation of positive change and adaptation of new technologies, and also in order to reduce the risk of adoption (McDonald and Brown, 2000). Incentives functioned to increase the degree of relative advantage and thus the rate of new technologies' adoption (Rogers, 2003).

Another important factor in farmers' adoption of new technologies is access to credit. This is mainly important for certain new technologies that need intense investment in the beginning such as tree planting in agroforestry (Feder et al., 1985). In order to overcome this constraint, especially for farmers who lack capital, one approach is through credit as there are government incentives for the application of new technology (Sunding and Zilberman, 2001) and to help farmers cope during the "waiting period" from planting until they get a better result from the adoption of new practices (Ajayi et al., 2006). Just and Zilberman (1983) introduced a credit constraint in their static model of adoption under uncertainty. They found that initial credit early in the diffusion process will enhance adoption and will thus facilitate further adoption. For example, credit is generally found to have a significant effect in stimulating farmer adoption of land and water management (Shiferaw et al., 2009). Holden and Shiferaw (2004) found that increased access to input credit for fertilizer may reduce farmers' costs in adoption. Also, a review of studies found that lack of credit significantly limits adoption of high yield variety technology as usually it needs more capital(Feder et al., 1985). A study in Malaysia indicated that smallholders were keen to adopt new technologies only when the relevant inputs were subsidized (Sail and Muhamad, 1994). However, incentives and credits have both positive and negative aspects (McDonald and Brown, 2000). Rogers (2003) mentioned although incentives increase the quantity of adopters, there is a possibility that the quality of adoption is low.

2 Infrastructure

Lack of physical infrastructure may present other barriers to adoption. Physical infrastructure such as transportation, communication and market facilities may constrain the adoption of an innovation and affects both farmers and extension. The capacity to move people, inputs, and produce and to send and receive information influences extension activities and capacity. This also applies to the production and distribution of other inputs such as fertiliser and pesticides. Shortage of seedlings and other planting material has frequently been acknowledged as one of the most important constraints on the adoption of agroforestry (Ajayi et al., 2006) and this has happened in the case of the adoption of clonal rubber in Indonesia as the areas of smallholders' rubber in this country are large in acreage. For example, one of the reasons for less adoption of rubber technologies by smallholder farmers in Sumatra, Indonesia was due to the main inputs (such as clonal seedlings, fertilisers, pesticides) not being available or difficult to obtain at the farm level (Supriadi and Chamala, 1998).

3 Institution

In the institutional setup some factors such as government policy, extension services, the role of local/national governments and Non Governmental Organisations (NGOs) and the political situation may influence decision making in adoption (Kiptot et al., 2007). NGOs and international donors have been involved in agroforestry including rubber agroforestry (Current et al., 1995). Some of the decisions of farmers may be influenced or linked to the policy at different levels. Doss (2006) proposed policy variables that need to be incorporated in the study of the adoption of new technology in agriculture, namely access to credit or cash, access to information and access to labour markets.

3.3.6 Farm and Farm Household Preferences

In most developing countries, the level of participation in any production activity can be linked to the socioeconomic status of households (Agarwal, 1983) and it is essential to observe the adoption of traditional agroforestry in relation to the economic and farming conditions of households (Sood, 2006). Resource endowment is generally positively correlated with the probability of the adoption of new technologies (Pattanayak et al., 2003).

1 Farm size

Rogers (1983) mentioned that earlier adopters have larger-sized operations than later adopters. The role of farm size on the decision to adopt new technologies may differ for each case study, characteristics of the technology and location. More particularly, the influence of farm size on adoption also depends on other factors such as fixed adoption costs, risk preferences, human capital, credit constraints, labour requirements and tenure arrangements (Feder et al., 1985). In some cases, the effect of farm size is found to be positive and significant and people with larger farm sizes are more likely to adopt new technologies. For example, a study of adoption of conservation technology showed that large farms could reflect greater capacity that encourages conservation (Cramb, 2000). Further, in the case of the adoption of technology of agricultural conservation in Africa it was noted that the farmers on smaller farms declined to adopt farming conservation (Amsalu and de Graaff, 2007). Farmers who had more land had more opportunity to use new practices on a testing basis and more ability to deal with risk (Nowak, 1987). However, in the case of India, farm size and age were not significant in the farmers' decisions on whether or not to intercrop in rubber smallholdings (Rajasekharan and Veeraputhran, 2002).

2 Household Income

Most studies have assumed that farmers with higher incomes are more likely to adopt agroforestry practices than farmers with lower incomes. According to theories of innovation adoption and livelihood strategies, households with a higher socioeconomic status and with more capital can accept the risk of adopting new technologies more easily and become innovators or early adopters (Rogers, 2003; Scherr, 1995). There is evidence that in agroforestry practices adoption is different between the average and poor groups (Scherr, 1995) as the smaller farmers think the new technologies are too risky (Gershon and O'Mara, 1981).

For example, a case study in India showed that households who have land and a higher income are more likely to adopt agroforestry practices (Alavalapati et al., 1995). Another study in Africa suggested that poorer farmers cannot afford to wait long enough for trees to be cut for timber production (Scherr, 1995). However, more local information on household characteristics and resources is still needed to know fully the nature of these relationships (Scherr, 1995).

The variable off-farm income has a different influence on the adoption of new technologies. The off-farm activities of the farmers included in this case can be their activities to earn cash through employment in the public or private sectors, self employment, and nonfarm business. Off-farm income demonstrated a highly significant association with the extent of agroforestry adoption (Sood, 2006). The effect of off-farm income could be positive in terms of additional capital and negative in time available for new practices (Rajasekharan and Veeraputhran, 2002).

Farmers with off farm income have more opportunity to adopt the new technologies as with their additional income they can provide the cost of new practices. Off-farm income can help to overcome a working capital constraint or may even finance the purchase of a fixed-investment type of innovation (Feder et al., 1985). Also, farmers with off farm income are less risk averse than farmers without it (Sharma and Kumar, 2000). For example, the two studies in India showed that the adoption of agroforestry was higher with farmers who were engaged in non-agricultural activities (Eppen, 1994; Sharma and Kumar, 2000). Pender and Kerr (1998) in their study in Ethiopia also found that households who had a secondary income source invested more in stone terraces than farmers without off farm jobs.

However, the negative influence of off-farm income on farmers' adoption of new practices such as agricultural conservation investment was found in several studies (Amsalu & de Graaff; 2007, Tenge et al., 2004). For example in the case of adoption of conservation terraces technology, farmers in Africa who were involved in off-farm activities in the city, made less use of stone terrace (Amsalu and de Graaff, 2007). This might be due to competition and overlap in labour allocation between working on applying new practices and off-farm activities. The farmers also need more income to face increasing demands in their daily life and thus there is less time available to learn new farming practice (Amsalu and de Graaff, 2007; Shiferaw et al., 2009; Tenge et al., 2004).

3 Family size

Family size might have a different role in adoption, related to the role of family members as the main sources of labour in farming activities. In other ways increased family size affects the demand for more production to feed family members. In the context of agroforestry, the number of family members has a variable effect on the adoption of new technologies. In the case of the African study, Nkamleu and Manyong (2005) mentioned that household family size is positively and significantly related to farmers' adoption of live fencing and apiculture. This indicates that larger families with an increased labour supply are more likely to adopt the technologies than smaller households. The effect is therefore positive (Amsalu and de Graaff, 2007).

However there was a decline in the extent of agroforestry adoption with increased availability of family labour for agriculture. For example, the study of Sood (2006) in the Western Himalayas showed that agroforestry adoption increased when farmers had a smaller family. This is probably because planting and managing trees are less labour intensive than agriculture (Agarwal, 1983; Arnold, 1997; Sood, 2006). In this case farmers do not need more labour and to spend more time in replanting as they have benefited from further natural regeneration of trees. Meanwhile a study in Costa Rica (Jones and Price, 1985) using the number of sons working on the farm as an indication of family labour supply, found that there was no correlation between shortage of family labour and the adoption of a tree planting programme.

4 Education

Education is often mentioned as a factor that influences the adoption of new agroforestry technologies. According to Rogers (2003) earlier adopters usually have better education than later adopters and they tend to have more contact with outsiders such as extension workers. This is supported by Mercer and Pattanayak (2003) who report that some studies showed that new technologies tend to be adopted faster by households with a higher education level and by those farmers who had more informal education. In the case of adoption of cocoa by Indonesian smallholders, Pomp and Burger (1995) found that education affected cocoa adoption positively. The same positive influence of education in the case of the adoption of terrace conservation was found in India (Glendinning et al., 2001), in Africa (Nkamleu and Manyong, 2005) and in the Philippine highlands (Lucila et al., 1999).

In the case of adoption of tree planting in the farms in India, younger farmers with better education developed a positive attitude towards tree growing (Sood and Mitchell, 2004). The reasons for this are probably that people with higher education are better at understanding the problems and they have more capability to access, process and use relevant information about new technology in their farming (Hornik, 2004). In addition, the farmers with formal education have more mobility and more exposure to the outside world and agency contacts, therefore they might have been more positively influenced to adopt and apply new technologies (Sood and Mitchell, 2004). However, in some cases the different educational levels lead to less adoption. In the case of a complex technology there are possibilities for farmers with a high level of education to learn all the limitations and negative effects of new practices, therefore they may tend to reduce or delay adoption (Pannell et al., 2006).

5 Age and Experience

Age appears to be of particular relevance to the adoption of new technologies. The most extensive review of socio-economic factors influencing adoption found both positive and negative relationships between age and adoption (Rogers 2003, Baidu-Forson,1999;)

and there is also inconsistency of evidence about the relationship between age and innovativeness (Pannell et al., 2006).

In some cases older people are more keen to adopt new technologies because they have had more years of farming experience (Baidu-Forson, 1999; Tenge et al., 2004), more personal capital from long accumulation (Nkamleu and Manyong, 2005) and limited participation in off-farm activities (Tenge et al., 2004). Thus the older farmers may be more likely to invest in new technologies. The argument that older farmers happen to be resistant to new technologies might not hold true everywhere and at all times (Amsalu and de Graaff, 2007). In contrast, the study of the adoption of cocoa in Indonesia indicated that adoption increases with age because young households have relatively small landholdings (Pomp and Burger, 1995). In Africa the low level of adoption among young farmers also could be due to their small farm size (resulting from the inheritance system) and their involvement in off-farm activities (Tenge et al., 2004).

However in some studies, younger farmer were more likely to be keen to be early adopters of new technologies than older farmers (Alavalapati et al., 1995; Sharma and Kumar, 2000) which is why the influence of age was commonly hypothesised to be negatively related to adoption of technology (Rajasekharan and Veeraputhran, 2002). This is linked to reasoning that younger farmers are more flexible in dealing with risks (Akinola, 1986; Akinola and Young, 1985; Voh, 1982) and young people have more energy (Nkamleu and Manyong, 2005). Meanwhile older age is speculated to have a high correlation with physical health problems (Pannell et al., 2006) and old farmers stick to their traditional ways of farming (Tenge et al., 2004). However, these factors can also depend on and be related to the other factors.

Some scholars linked the length of experience with the age of farmers, as an older age was linked with length of farming experience and could positively influence the adoption of new technologies. In the case of the adoption of improved fallow in Africa, farmers' experience in farming cultivation positively and significantly influenced adoption, suggesting that the higher the level of experience the higher the probability of farmers adopting improved fallow (Nkamleu and Manyong, 2005). However farmers with long experience might reject the new practices as they are satisfied with the traditional system (Tenge et al., 2006).

3.4 Decision Making Models in the Adoption of Agroforestry

3.4.1 Decision Making Models

As mentioned earlier, the adoption behaviour is most likely affected by different factors related to the new technology, farmers' characteristics, farm characteristics as well as biophysical institutional and social context. Therefore, explanations of how these variables affect a farmer's decision-making process in technology adoption are expected to be complex. In addition the process of adoption is complicated, dynamic and the various factors are likely to influence one another and cause mutual interdependencies. This section will discuss frameworks that can be used for identifying the common pattern of a farmer's adoption-decision process.

There are some decision making models that can be used as approaches to analyzing the adoption of new technologies by smallholders in Indonesia. Based on their review of farmers' investment behaviour, decision making models can be divided into economic perspectives and socio-economic perspectives (Brase and La Due, 1989). Economic perspectives usually apply statistical models with cost and other quantitative variables in equations to predict decision makers' behaviours under certain situations. In addition, Clark and Staunton (1989) observed that adoption studies have been dominated by a separation of analysis between economists, sociologists, and geographers. The different disciplines' approaches to models are not necessarily contradictory, but represent different aspects of the adoption process (Boahene et al., 1999; Mercer, 2004).

In most economic studies, adoption is categorised as dichotomous. The decision to adopt a technology or not is a binary decision, it takes on two values: 1 or 0 (adopt or not adopt). Three types of models have been proposed in the econometric literature for estimating binary choice models: the linear probability, logit, and probit models. Logit and probit models have been extensively used in the study of farmers' decisions to adopt conservation technologies (Baidu-Forson, 1999; Franzel et al., 2001). Both of these models provide the possibility of analyzing the probability of adoption or non adoption (Amsalu and de Graaff, 2007).

Some researchers have argued that economic models cannot cover all the complications of the decision making process, especially in developing countries, as decisions are not only based on economic parameters and mathematical forms; they are subject to a combination of economic, social, and cultural factors (Boahene et al., 1999). Some socio economic models include factors such as personality, attitude and behaviour. Supporters of socio economic models try to integrate all non-economic factors in the model including education, age, experience, land ownership, farm size, family size and belonging to a farmers' group. Thus farmers in the same environment may have different objectives and livelihood strategies, and so respond differently to a given technology (Scherr, 1995).

Meanwhile, sociological studies have long been interested in the factors that influence the adoption of new technologies across groups, communities and countries. According to Johnson (1980), sociologists use descriptive models which lead to understanding what people do and why.

Gladwin (1979) introduced Ethnographic Decision Tree Modelling (EDTM) which allows farmers to consider all the options in the decision process. This cognitive model is suitable to cover the decision making by farmers in rural settings and their natural information. The cognitive models translated farmers' behaviour in decision making from the field to research format (Gladwin, 1980) and allow the farmers as decision makers to decide the factors that influenced their decision. This leads to discussion of ethnographic decision tree modelling in part 3.4.2.

3.4.2 Ethnographic Decision Tree Model (EDTM)

Ethnographic Decision Tree Models (EDTM) were proposed and named for the first time by Gladwin (1979) who recommended a cognitive approach for decision making in agriculture adoption research. Gladwin defined ethnographic decision tree modelling as a "*technique to elicit the decision criteria from the decision makers themselves using ethnographic fieldwork, which is then combined in the form of a decision tree, table, flowchart or set of if then rules*" (Gladwin, 1989a, p.8). She argued that EDTM is "*better in reflecting actual decision making*" by using cognitive capabilities. Cognitive means relating to the mental process in knowing, learning and understanding how people make a decision. This cognitive approach may be used for accessing decision making in adoption research as this is better at reflecting actual decision making. As mentioned before, decision making is a mental process, thus the model also can be used to understand decision making as a mental process. Her argument is that because farmers as decision makers have limited access or processing capacities to process all information available, they tend to have simpler procedures for their decision making and often use simple rules of thumb that may show their lack of ability to sort choices all at once, and part of their strategies to deal with uncertainties (Gladwin, 1980).

The theory behind this EDTM is that people have the ability to report on real life decisions in terms of the options evaluated, the dimensions of contrast and sequencing comparisons, and they produce a certain pattern (Gladwin, 1989b). In choosing alternatives, Gladwin (1979) stated that people do not make complex calculations of the overall utility of each alternative. It is assumed that farmers are experts in making their own decisions; they construct their decisions in a hierarchical manner using simple rules of thumb and compare alternatives using separate criteria without quantitatively ranking the available options. Then decision making is reflected in a decision tree composed of a sequence of discrete decision criteria (Gladwin et al., 2002b) that is now accepted as a descriptive and predictive model that examines real world decisions and the criteria that influence those decisions (Darnhofer et al., 2005; Gladwin, 1989a; Gladwin, 1989b; Murray-Prior, 1998). Messerschmitt (1992) stated that cognitive models of the farmers' decision making process translate farmers' behaviour from the field to research format and bring the farmers' knowledge to research. Importantly, EDTM enables the researcher to obtain a complex understanding of the criteria that influence participants' decision-making with regard to a specific subject (Roth and Botha, 2009) and in the process it consists of three phases (i.e., exploration, model development, and model testing).

1 *Exploration*

The main characteristics of the EDTM are the ethnographic interview and construction of the decision tree. This EDTM is based on individual ethnographic interviews and participant observation that look into decision criteria from decision makers (Gladwin, 1989b). Gladwin (1989a) proposed using ethnographic interviews and participant observation strategies were developed by Spradley (1979) to elicit decision criteria. Gladwin integrated this ethnographic interview in the decision model to investigate farmers' decision making process in the real situation. This ethnography is widely used in the study of the understanding of farmers' reasons for farming and reasons behind the decision of farmers to use new technologies (Rusten and Gold, 1991). This ethnographic interview also allows participants to express their belief about as criteria for their decision and they influencing their decision and may explain about the reasons for their action or decision (Gladwin, 1989b) . This is to obtain the decision rules used by farmers in their natural life and based on their traditional strategies of farming. A decision tree model is the main outcome of EDTM.

The EDTM can be used as an approach to understand decision making as a mental process of farmers in the adoption of improved rubber agroforestry technology, for several reasons. Firstly the EDTM uses eliciting techniques to specify the actual decision criteria (Gladwin, 1989b). By using ethnographic eliciting techniques, decision criteria can be elicited directly from farmers as decision makers themselves. Ethnography is a strategy of inquiry in which the researcher studies intact cultural groups in a natural setting over a prolonged period of time by collecting, primarily, observational and interview data (Creswell, 2007; LeCompte and Schensul, 1999). In addition the researcher may avoid making improbable behavioural assumptions about how people in the real world make decisions as the model uses more realistic assumptions of the individual's cognitive capabilities. Listening directly to criteria and constraints of farmers is more important for the successful adoption than the researcher alone doing the reasoning for farmers (Gladwin, 1979). Decision criteria elicited are discrete questions followed by either 'true' or 'false' answers for any particular subject.

6 Model development

Decision criteria in a tree are mentally processed so that alternatives are compared on each criterion separately, and all of them may not be processed by all individuals, which leads to the path structure of the tree (Gladwin et al., 2002a). To build a decision tree might provide an easier and cheaper model for the adoption decision model as this can be composed and tested manually or by using computer programmes (Gladwin, 1989b).

The decision tree diagram is useful in structuring the sequence of a decision and allows one to break down a big decision problem into a series of smaller problems that may be solved separately (Escalada and Heong, K.L., 2009). A comprehensive decision tree is developed which represents the participant group's thinking and reasons for their decisions (Roth and Botha, 2009). The decision tree also enables participants to see an arrangement of possible options as well as the chronological nature of decisions (Escalada & Keong, 2009). In the decision tree model an adopter has to pass all constraints; profitability, risk, labour, and capital. Non adopters can pick out one of the reasons they did not adopt. Therefore, EDTM analyses important factors in the farmers' decision path; it also helps in the understanding of possible limitations with decision choices. Based on this information, therefore interventions and approaches can be made for better adoption.

7 Model Testing

The last phase is model testing. This model is capable of being tested, because cognitive models which use ethnographic methods to elicit and specify decision criteria directly from the decision makers' point of view have more realistic assumptions. After the decision tree has been built, then the decision tree can be tested on other individuals in the group of decision makers. The main aim of the test is to confirm and to validate the decision criteria which were developed based on the first interviews and to predict the behaviour of people in that group in making decisions (Gladwin, 1989b). Thus, if a certain set of criteria is true for a participant, the tree would predict their decision in advance of observing what they will do (Roth and Botha, 2009).

The decision trees method has been applied in predicting the actual choices of individuals and it resulted in a high degree of prediction. Applications of this model in various studies show that this model has been tested and the predictability is 80-95% of individual choices (Murray-Prior, 1998; Fairweather and Campbell, 1996; Jangu, 1993; Gladwin, 1989a). For example this was the case for the prediction of decisions made by Ghanaian fish sellers in selling fish, farmers' adoption decisions in Puebla, Mexico, farmers' land use patterns in Costa Rica, and farm families' choices in Mexico (Gladwin 1983). Further, Gladwin concluded that one of the strengths of EDTM is that the model can be tested by predicting choices from other farmers' decisions (Gladwin, 1989b).

This method has been used in some studies in decision making in adoption (Gladwin, 1975), in the adoption of improved fallow in Zambia (Gladwin et al., 2002a), and adoption of an incorporation of fish and prawn with rice in Indonesia (Sambodo, 2007). This model also has been used in a study of the adoption of agroforestry technologies and natural resource management by Swinkels and Franzel (1997). They showed that the decision tree model allowed identification of constraints on adoption and a detailed examination of the decision making process by breaking the process into a series of sub-decisions that formed in branches of the tree. Fairweather (1992) used this approach in finding how farmers in Hawkes Bay, New Zealand made decisions regarding tree planting in their farming system. Wurjanto (2001) used this method to find out the reasons behind farmers' decisions on planting trees in Indonesia.

There are difficulties in the method of ethnographic decision modelling. The process of interpreting and combining the individual interview and building the decision is usually time consuming and difficult (Murray-Prior, 1998) and the translation of criteria into questions can also be complicated (Locke, 2006). As a result there is some limitation in criteria in the decision tree. The real process may also not take the same stages, steps and conditions considered in the model, as the model is only a simplified picture of a part of the real world (Gladwin, 1989a page 13, Locke, 2006). This limitation emphasizes the fact that the decision tree is a decision model; just like a map must distort proportional size to depict relative position, the decision model must misrepresent some aspects of decision making in order to be successful (Locke, 2006). When constructing the decision tree, several decision criteria may not be represented on the final decision tree made during this study that deserves more explanation in the discussion of the decision tree. To complement the Ethnographic decision tree model as qualitative model and especially to find out significance of the variables or criteria to the decision, there is discussion below about application of Logistic regression in this study.

3.4.3 Logistic Regression (Logit)

Most of the studies on the adoption of technologies in agroforestry focus on adoption behaviour for a particular technology at a single point in time. Even though adoption of agroforestry by rural people is a dynamic process that occurs over a long time period, most of the studies in this adoption are based on a single snapshot in time (Kiptot et al., 2007; Pattanayak et al., 2003). The single equation models including logit and probit are usually used in most agroforestry studies. Logit regression may be useful in the analysis of significant factors that relate to a decision of adoption of agroforestry technology (Gladwin, 2002a).

Logit regression was used in this analysis to see if any of the variables in the decision criteria were significantly related to a dependent variable representing adoption of agroforestry technology. Logit is used in this study as it allows the prediction of a dichotomous result from a group of predictor variables that can be continuous, categorical, and dichotomous or a combination of any type of these (Green, 2001). In addition, the logistic transformation of the binomial is easy to interpret (Bewick et al., 2005).

There are several applications of logit and probit in the study of the adoption of agroforestry technology, such as in the adoption of live hedges in the central plateau of Burkina Faso (Ayuk, 1997), the adoption of mixed inter-cropping agroforestry technology, *Gliricidia sepium* and maize, in Malawi (Thangata and Alavalapati, 2000), the adoption of ‘no-tillage’ technologies in Pakistan (Sheikh et al., 2003), the adoption of alley farming by farmers in the forest zone of southwest Cameroon (Adesina et al., 2000), analysis of factors influencing farmers decisions on tree planting in Bangladesh (Salam et al., 2000), the adoption of agroforestry by farmers in the hills area of Nepal (Neupane et al., 2002), the adoption of agroforestry technologies of improved fallow in Cameroon (Nkamleu and Manyong, 2005), farmers’ adoption of tree-based fodder technology in Zimbabwe (Jera and Ajayi, 2008) and the adoption of improved fallows in Eastern Zambia (Gladwin et al., 2002a).

3.4.4 The Qualitative and Quantitative Analysis

As explained before the adoption of new technologies in agroforestry depends on a combination of social, economic and cultural factors so that is why different disciplinary approaches are needed. No single model can describe all aspects of adoption of smallholder farmers as response to introduction of new technologies (Thangata & Alavalapati, 2003). In some parts of the world agroforestry technologies have failed due to low adoption rates, and it is argued that both quantitative and qualitative socio-economic research are needed to understand how smallholder farmers view and understand new technologies and maximise synergy (Kiptot et al., 2007) and so both are used in this thesis.

The qualitative method using ethnographic case studies has an emphasis on processes and meanings that are not rigorously examined or measured. Meanwhile quantitative studies give emphasis to the measurement and analysis of relationships between variables not processes. Qualitative research methodologies complement quantitative research approaches; they provide insights into farmers' adoption patterns and improve the understanding of the process of adoption of agroforestry technologies from the perspective of farmers (Ajayi et al., 2006).

Qualitative method can reveal a wide range of issues that could not have been obtained from the formal survey, for example farmers adopting technologies as a means to obtain credit and for status (Kiptot et al., 2007; White, 2002 and Place et al., 2007). Decision trees contain all the criteria processed by individuals in a group and regression analysis highlights those that are significant in the behaviour of that group (Gladwin et al., 2002a). Decision trees may provide the reasons people do not adopt the technology by identifying all the decision criteria and limiting factors in technology adoption. Gladwin et al. (2002a) used a combination of decision tree and logit probit analysis to increase the rigor of the decision tree and used statistical (quantitative) analysis to test the hypothesis that derived from the results of the decision tree model. Logit analysis can be used to measure the statistical significance of choice factors identified as important in the decision tree model (Gladwin et al., 2002a).

The combination of decision trees and logit is a good example of a combination of quantitative and qualitative approaches. This combination analysis shows that the application of cognitive decision model and econometric testing can improve both approaches (Mercer, 2004). In addition, regression analyses will provide the policy maker with a statistical test of significance of variables that influence the adoption process. Therefore, the factors in a decision tree which are significantly related to the adoption of clonal rubber by smallholder farmers in Indonesia can be identified.

3.5 Summary

The diffusion and adoption of agroforestry technologies can be approached using Rogers' theory on decision and innovation. However as agroforestry technologies have some differences compared to the adoption of agriculture such as more complicated agroforestry components and longer waiting periods to get results, this study also adopts an approach that is used by other researchers in agroforestry adoption.

From the review of factors influencing the adoption of new technologies it can be highlighted that the adoption of new agroforestry technologies is not a simple process. It can be influenced and depends not only on the relationship between technology and farmers' characteristics, but also on a combination of various factors. These include household factors (e.g. age, education, experience), technological factors (e.g. labour input requirements, complexity, compatibility, technical knowledge etc), social status, institutional and policy factors (e.g. land tenure system, incentives, credit) and geographical factors (e.g. access to roads and markets, location of a village etc).

The process of adoption is complicated, dynamic and the various factors are likely to influence and be interdependent on each other in the decision making process. In general, the factors which influence farmers' decisions on the adoption of new agroforestry technologies can vary. The factors that affect the adoption can be having a positive influence on farmers' adoption decisions, having negative impacts and having no direct effect or depend on other factors.

This study uses a combination of a qualitative approach represented by the ethnographic decision tree model (EDTM) and a quantitative model (logistic) to gain a deep insight into the decision making on the adoption of new agroforestry technologies, especially the rubber agroforestry system as well as highlighting the factors influencing farmers' decision making. Therefore, the next methodology chapter will describe the process used to elicit data, build a decision tree and test it, as well as the survey to complement the cognitive model which is analysed using a logit regression model.

Chapter 4 Methodology

4.1 Introduction

This chapter presents the characteristics of the locations of the study in detail as well as the methods used in data collection and the sampling frame. A review of techniques used for processing the data and the conceptual model for analysing including their limitations is also developed.

4.2 Characteristics of the Study Areas

As mentioned in Chapter 2, rubber agroforestry developed quickly in some provinces in Indonesia, especially Sumatra and Kalimantan. Two of the main provinces which have large areas of smallholding rubber and a high number of rubber farmers are Jambi and West Kalimantan. Jambi is the second biggest province producing rubber in Indonesia after South Sumatra Province. In addition clonal rubber has been replanted in these two provinces to increase rubber production in Indonesia. These two areas also have been introduced to the project of Rubber Agroforestry Systems (RAS) (Rahman and Haris, 2009) run by ICRAF and other research institutions. Therefore Bungo District in Jambi and Sanggau District in West Kalimantan provinces were selected for the case study sites. Comparison of the two districts provided important insight into good practice for introduction of clonal rubber.

4.2.1 Bungo District Jambi Province

1. *Geography*

Jambi Province is one of the provinces in Sumatra Island, geographically located between 0° 45' - 2° 45' south latitude and 101° 10' - 104° 55' east longitude. The area of Jambi Province is 53,435 km^2, divided into 11 districts/regencies. In 2008, the population of Jambi province was 2,788,269 people (Jambi, 2008). The majority of the population is of Melayu ethnicity and most of them are Muslim.

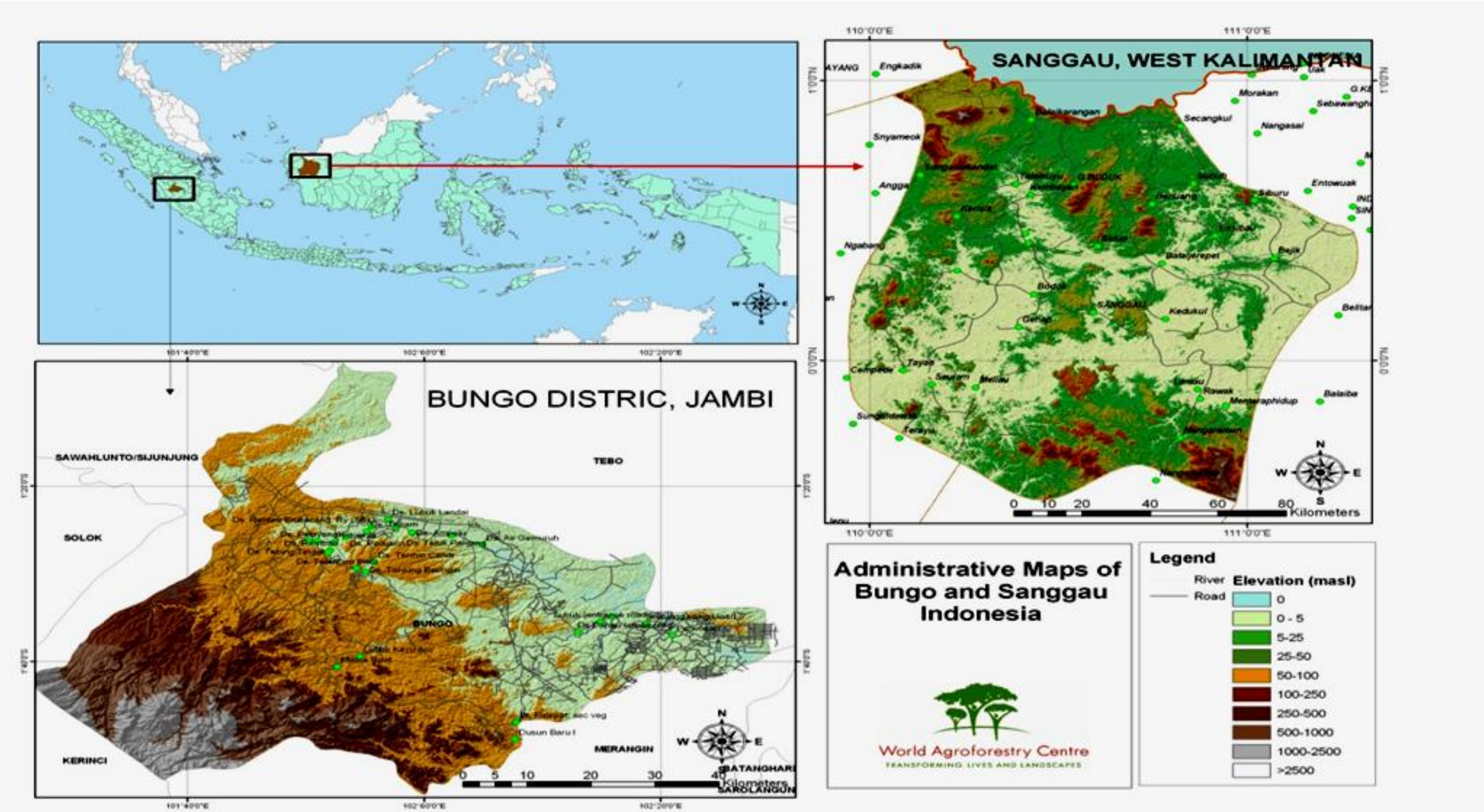


Figure 4.1 Map of Indonesia and the locations of study

In 2008, the agricultural sector was the biggest contributor to the economy of this province. Agriculture contributed 31.09% to the total Gross Domestic Regional Product (GDRP) of Jambi, including the biggest contributor, estate crops (13.97%). It was reported that rubber was the highest income contributor from the export commodities of Jambi and replaced pulp and plywood that had been the previous main exports of Jambi province. Rubber smallholding has an important role in economic and rural livelihoods. Rubber was the main estate crop in Jambi Province and the planted area of rubber was 565,000 ha in 2005 and increased to 643,338 ha with production of 1,035,300 tonnes in 2008. Around 246,380 households in Jambi are rubber farmers and their main income comes from rubber plantation. There were 11 rubber factories in 2008 in Jambi, with capacity of 293,100 tonnes/year. The other important commodities are oil palm, with 2008 production of 1,156,414 tonnes, and coconut 116,714 tonnes (Jambi, 2008).

Bungo district is one of the districts in Jambi province that has a large area of rubber smallholdings. This district covers 716,000 ha in the west part of Jambi. Geographically its position is 1° 08' - 1° 55' south latitude and 101° 27' - 102° 30' east longitude, located in the centre of Jambi Province. The altitude of this district ranges from 70m -1300m above sea level and the average temperature in the area is 25.8° - 26.7° The type of soil in the Bungo district consists of podzolic and latosol (44%) (Bagnall-Oakeley et al., 1996).

The distance from the provincial capital is 236 km. The main river is the Batang Tebo River and administratively the district is divided into 17 sub districts and 137 villages. The population of Bungo District in 2005 was 381,221 and the majority of the people were Muslim (Bungo, 2008) .

2. *Land Uses*

In the past the Bungo district was mostly covered by lowland-tropical forest but other land use systems have been applied and have decreased the dominance of forest. The forest area in Bungo district can be categorised as forest production (Harris, 1998), forest protection (12,000 ha) and National Conservation areas (27,300 ha). Forest has decreased because of logging, forest fires and conversion of the forest to other purposes such as agriculture and plantation including rubber and oil palm. In 2005, smallholders' rubber tree areas were estimated at 70,659 ha with rubber/dry latex production of 23,150 tonnes, or on average was 350 kg/ha/year. There were 44,746 households of rubber farmers dependent on rubber production for their livelihoods. In the year 2008 this area increased to 96,271 ha and total production was 28,120 tonnes and productivity was 709 kg/ha/year.

Oil palm is the second largest commodity in Jambi and the oil palm area in 2005 in Bungo was 32,843 ha and total production was 194,345 tonnes per year. This area is divided into big private estates, 10,265 ha, government programmes 11,480 ha, and smallholding oil palm plantations, 2,086 ha. In 2008, the area increased to 49,602 ha with total production of 145,221 tonnes per year, as shown in Table 4.1.

Table 4.1 Planted area and composition of plantations in Bungo regency in 2008

Commodities	Area (ha)				Production	Productivit y
	Total	TBM	TM	TT	(tonnes/year)	(Kg/ha)
Rubber	96,271	28,167	39,646	28,458	28,120	709
Oil Palm	49,602	10,385	39,062	155	145,221	3,178

Notes: TBM = Immature crops, TM = Productive/mature, TT/R = (damaged/old crop), Source : (Bungo, 2008).

1. *Economics*

Economically Bungo still depends on natural resources. The main contributor to the GDRP (Gross domestic regional product) or economy is agriculture (43%) including the contribution from smallholding rubber (Table 4.2). This is supported by two rubber factories with total capacity of 84,000 tonnes/year.

Table 4.2 Percentage distribution of Gross Domestic Regional Products (GDRP) of Bungo District in 2004-2005

No	Economic Sectors	Year	
		2004 (%)	2005 (%)
1	Agricultural	44.82	43.33
2	Trade, Hotels & Restaurants	16.04	16.29
3	Service	13.56	14.01
4	Transportation & Communication	7.31	7.21
5	Construction	5.70	6.27
6	Financial, Ownership & Business Services	5.06	5.32
7	Other	7.51	7.57
	Total	100%	100 %

Source : (Bungo, 2008)

4.2.2 Characteristics of the Villages

The locations for study in the Bungo district, Jambi provinces were four villages, namely Rantau Pandan, Sepunggur, Lubuk Kayu Aro and Pulau Temiang. ICRAF's project in the rubber agroforestry system has been implemented in these villages. The locations were categorised into two groups; locations for developing the decision tree model (Villages 1 and 2) and for testing the decision tree (Villages 3 and 4). Characteristics of the villages are summarised in the table 4.3.

Table 4.3 Summarised socio-economic conditions Rantau Pandan (village 1) and Sepunggur (village 2)

	Locations for developing decision tree	
Characteristics	Rantau Pandan	Sepunggur
Topography	Piedmont/hilly	Peneplain
Land Uses	Wet paddy land, Settlement, Ladang Rubber, Forest,	Settlement, Ladang Rubber, Forest,
Land availability	Access to Forest land, no free land, no certificate	Scarce, Limited land
Farming system	Extensive system; slash and burn, intensive paddy , animal (cattle and buffalo), Jungle and clonal rubber	Extensive system; slash and burn, no animal husbandry, local and clonal rubber, oil palm
Problems jungle rubber	Low productivity	Low productivity, Fungi
Distance to rubber	Close 1-3km	Far (3-5 km)
Population density	Low : 30/km2	High
Ethnicity, religion	Jambi (Muslim)	Jambi (Muslim)
Farmers group	Farmers' group not active,	Farmers' group not active
Road facilities	Asphalted main road, gravel and no constructed road to rubber garden	Asphalted main road, no constructed road to rubber garden
Distance from district centre	31 km	20 km
Technology introduction (Year)	Clonal rubber by ICRAF (1996) and Government (2005)	Clonal rubber ICRAF (1996, 2004) , Forest Dept (2002)
Demo plots	5	9

Sources: Penot and Budiman (1998), Mulyoutami (2008) and field observation (2008)

Characteristics of villages as locations for testing the decision tree model and survey are summarised in Table 4.4.

Table 4.4 Summarised socioeconomic conditions of Pulau Temiang (village 3) and Lubuk Kayu Aro (village 4)

	Location for the testing of decision tree model	
Characteristics	Pulau Temiang	Lubuk Kayu Aro
Topography	Peneplain;	Piedmont/hilly
Land uses	Settlement, rubber, wet paddy, forest and shared land with transmigrants	Wet paddy Ladang Rubber, forest, Imperata land
Land availability	Scarce, shared with transmigrants	Available for conversion, heritage land, no certificate
Farming system	More intensive system , no cattle or other animal husbandry, local and clonal rubber (monoculture)	Extensive system; slash and burn, intensive paddy, animal (cattle and buffalo), Jungle and clonal rubber
Local rubber	Low productivity	Low productivity
Distance to rubber location	Close 1-3km	Far (3-5 km)
Population density	Low	Low : 11.64/km2
Ethnicity, religion	Jambi (Muslim)	Jambi (Muslim)
Social group	Formal farmers' group Government' project	Working together, farmers' group not active
Road facilities	Asphalted main road, no construction road to rubber garden	Asphalted main road, gravel , no construction road to rubber garden
Distance from district centre	30 km	35 km
Technology introduction	Clonal rubber by ICRAF (1996), Government (2005)	Clonal rubber ICRAF (1996), Forest Dept (2002)
Demonstration Plots	4	1

Sources: Penot and Budiman (1998), Mulyoutami and field observation (2008)

Characteristics of rubber farming in Jambi are described below, including land system, labour system, tapping and marketing system and role of the women.

1. ***Land system***

The land tenure system acknowledged by people in the study area in Rantau Pandan and Lubuk Kayu Aro Villages is one of customary land titles called Tanah Batin or Tanah Nenek (Grandmother land). Tanah Batin is the land that mostly is used for community needs and cannot be privately owned. It is communal land and belongs to the village. This type of land is usually used for public facilities such as cemeteries, rivers, parks, schools and *lubuk larangan*[1]. *Tanah nenek* is similar to Tanah Batin, but is more related to the family lineage. The land may be used by each member of the family and is retained as valuable family land. Some of these lands are still in forest and others are fruit gardens. People may use land other than customary land for planting rubber or other purposes such as agriculture.

There are several different ways to get land for a rubber garden such as: (1) by opening new land from an unopened forest or old jungle rubber by using the slash and burn system; (2) inheriting land from parents or grandparents; (3) a transaction or buying the land from a family member or other farmers. Farmers may get land by clearing secondary forest in open access areas. The secondary forest itself belongs to the community and individual members of the community have the same rights of access to the forest.

The use of this forest is under the control of the "adat" (traditional customary law) leader. In some areas, the forests have been categorised by the Government. After land clearing, the farmers plant trees (rubber, timber, fruits or coffee) as a symbol that the land is considered to be private property that belongs to the farmer who cleared and planted. This land with trees usually belongs to the individual farmer who has secure land rights. This traditional custom/rule is the same for the land which has been used for permanent paddy rice fields and housing. Land cleared but not planted after several years is usually returned to the community for anyone's use. Land may be inherited by children or sold among communities. The village leader's approval is required if a farmer wants to sell to people outside the community. Some remote forest areas surrounding the village of Rantau Pandan and Lubuk Kayu Aro are still unopened and can be converted to rubber or agricultural purposes.

Farmers may inherit land from their parents or grandparents. In the location of the study, land is usually inherited by daughters. In general, inherited land in Jambi and other provinces on Sumatra Island are based on a matrilineal system. In this system land is traditionally owned by lineage members consisting typically of three

[1] *Lubuk larangan* is particular place where farmers cultivated and protected fish in the river. This traditional fishing control has been established from one generation to another. This place is fully managed by the villagers and some restrictions are applied such as prohibition on fishing outside schedule and restrictions on fishing by using poison, explosive materials, and electricity. This place is opened only at certain times and the villagers catch the fish for communal benefit.

generations descended from the same grandmother (Quisumbing et al., 2001). This system is applicable mostly to the wetland and upland paddy rice as it is mainly women who work this land. However, in the case of rubber gardens or forest land usually men work this land starting from clearing the land, planting and maintaining the rubber garden. For their efforts the lands are usually owned by the men. In their study case in Jambi Suyanto and Otsuka (2001) found that in the case of rubber land there is a gradual change from the matrilineal system and the mother may deliver her land to her daughters and even to sons individually. A son-in-law has access to his own hereditary land through marriage to a daughter. But he has to clear the land and plant it with rubber. Now, in the traditional system, communal land is becoming rare and most of the land is owned by a single family; husband and wife.

Farmers can own the land by purchasing land from a family member or other farmers. Land market transactions in the villages are becoming more common within the communities studied. However, land can only be owned by villagers; people who live in the village, or a man who is married to one of the villagers. People from outside the village or outsiders need the village leader's consideration and approval before they can own village land.

2. *Labour system*

There are three main labour sources in the farm labour system in Jambi namely family labour, paid and collective labour. The main source of labour is family members. Most of the work in the rubber plantation is completed by the farmer, his wife and his family (son, daughter, or son or daughter in law). Men usually do the heavy work such as cutting the trees, burning debris, fencing and digging holes for seedlings. Women usually help men with some parts of the land clearing, but mostly they are responsible for planting paddy rice, vegetables, preparing food and taking care of their children.

Traditional families are usually large with more than three or four children, but this is becoming less common with the new generation. The children help their parents until they get married and build new family/households. Before marriage, they share the latex; mostly it goes to their parents but the children can get some for their needs. If their children get married, the money mostly will go to the family of their children but they will also give some to their parents. There is no formal agreement between family members as this scheme is in order to help family members. Next, the new households will open their own new rubber agroforest by cutting and burning the forest.

The availability of family labour may be insufficient to fulfil all the labour demands of a rubber garden. In addition, working together as collective labour is not popular in the rubber garden and the rubber farmers depend on paid labour. Paid labour for some poor farmers is an opportunity for them to receive payment for work. But for the other farmers it means more costs that are difficult for them to afford. Wealthy farmers in the village may use labour to compensate for their time in other business, or they just have to use it as they have large areas of rubber.

There are different schemes to hire labour at different stages of rubber garden establishment. In getting land, wealthy farmers may open the forest or other old jungle rubber by paying other farmers to undertake the work. One side provides labour to open the forest ready for the planting of rubber seedlings, while the other provides cash for the land clearing, seedlings and fertiliser. When the rubber garden is established, the land is, with the rubber on it, divided in half or to what they have agreed to. In this system poor farmers can get access to land for cultivation with less capital and wealthy farmers obtain a developed rubber garden.

The other type of labour is collective labour or labour sharing agricultural activities. One of the characteristics of the villages in the study site is the existence of social groups. The farmers work together to help each other on their farms and on other occasions. There are some schemes of collective action that have been established in Rantau Pandan, Lubuk Kayu Aro and Sepunggur villages for generations including such traditional systems as: *Pelerin, Gotong royong, julo-julo, berselang and* farmers' groups.

Pelerin; is a labour sharing group among the community in private land. Farmers can join this group, but usually the members are neighbours in the village or they share land borders. They arrange a time for working based on their agreement and mostly during the season of planting paddy rice. A farmer who is not able to work when required must make it up by paying a daily wage or by offering unpaid labour on another day. This collective work is usually on individual land and more often agricultural land and wet paddy land, but rarely or never in their rubber garden.

Gotong royong; is collective action on communal lands, public facilities, and other village properties under non-private ownership. This activity is arranged by the village leader and is voluntary. The time is agreed in a meeting and the activities are agreed to by the community. There is no obligation to pay if absent but people are usually ashamed if they do not come.

Julo-julo; is collective capital (it can be money or rice) to be used for someone to carry out a big event such as being married or circumcised, a death or a birth.

Berselang; is labour sharing or collective labour for planting and harvesting paddy rice in the upland area usually using an extensive system. This working is on private individual land and mostly at the beginning of the planting season and at the end of harvesting. The owner of the land usually prepares food and drinks for the other farmers who are mostly young farmers. This system has become rare as the upland paddy system is seldom used now-a-days. Wetland paddy which is an intensive system introduced by the government has replaced the upland paddy system. Women are usually more active in the wetland paddy system and sometimes men are keen to help after finishing activities in their rubber garden.

Farmers' groups; Farmers' groups were formed mainly by the government for facilitating a connection between government agencies and farmers to exchange information, to simplify administration and to deliver information and/or incentives. Farmers' groups are established mostly if there is a government project, such as replanting clonal rubber or introducing new varieties of paddy rice. In agricultural activities, the focus for these groups is usually extension activities to maintain a high production of paddy rice.

3. *Tapping and marketing system*

There are two tapping systems common in the areas studied; tapping by the landowner and shared tapping. Some farmers undertake the tapping by themselves or with their wives. The reasons for this system being adopted are usually that they have sufficient time to do tapping as their land is not large and is relatively close to the village and they want to maximise the profit.

Other farmers choose the share tapping system which could be between families or a professional business matter. Share tapping within the family is in terms of helping each of the families involved. There is usually no clear agreement on how the money will be distributed. This system is usually applicable between parents and sons or sons-in-law who have just married and have no job or proper income who will tap the parents or parents-in-law's rubber while establishing a new rubber garden. This can also happen between other family members who offer share tapping to those who need money.

The other form of share tapping is between a landowner who has a large area of rubber garden or has another job and allows other farmers to tap his rubber garden with part of the latex yield as payment. This system is common and it plays an important role in community life as it is not only an economic relationship between workers and employees. There are unwritten agreements between landowners and share tappers such as (a) they usually divide the result of latex in the proportion 25% of the result goes to the landowner and 75% to the share tapper (worker).

The share tapper has to provide everything related to their job to tap the latex including: knives, buckets, and chemicals (rubber acids) and transportation to and from the fields. The share tapper should sell the yield to the landowner or via the landowner with the price determined by the landowner. If the share tapper sells to another buyer it will constitute breaking the agreement and the share tapper is refused any further work. The trust of the landowner in the share tapper is important and can be measured by the latex that the landowner gets from the share tapper. The share tapper has often borrowed money from the landowner to fulfil their daily needs and usually will pay off the money they owe with the money from the sale of the latex. This causes the share tapper to become very dependent on the landowner even though the market price from other buyers may be higher.

The situation is different if the landowner has a clonal rubber garden or a rubber garden with high productivity as the distribution of the yield changes to 50:50. The difference is because the yield is lower from jungle rubber trees and the share tapper needs more time to tap as the rubber trees are spread over a larger area. The share tapper needs to put in more time and effort to get the same yield.

There are different ways of marketing latex in Jambi. Most of the farmers sell their product to "*toke getah* " or middle men or collecting traders. They usually choose the toke because of reasons such as a family relationship and they sell to their family (traders) as it is a way of supporting their family to become big traders. Other reasons are because they have a share tapper/share tapping agreement or they have an agreement for paying off a debt. Another method of selling latex is through an auction system. In this system farmers can take their rubber latex directly to the auction. In the auction system the farmer usually receives a better price because of competition between buyers and the process is more transparent.

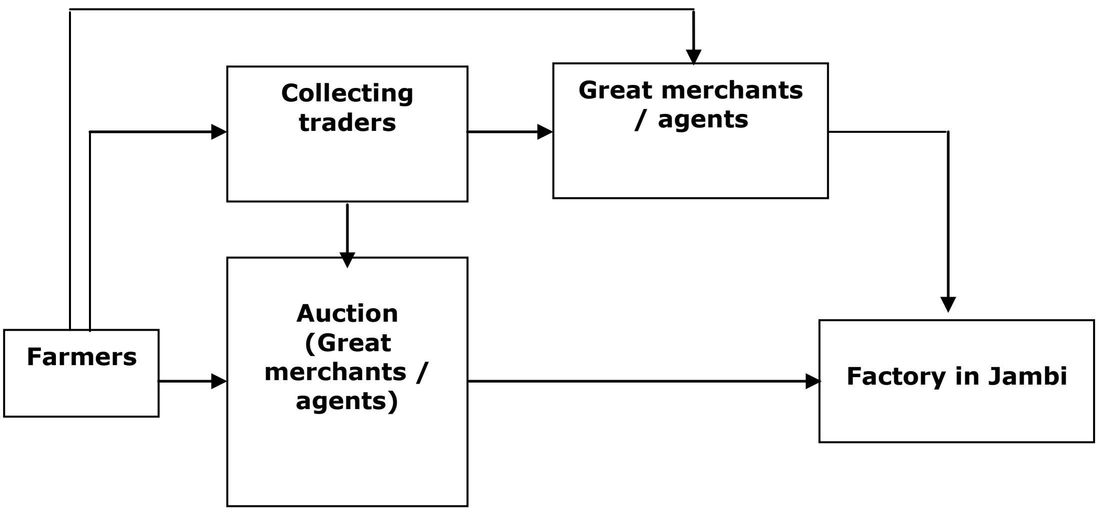


Figure 4.2 Raw rubber material marketing channel in Jambi (IRRI and ICRAF, 2006)

4. *The role of women in Jambi in rubber cultivation*

Most of the work in rubber farming is undertaken by men especially in preparation of the land. Meanwhile, women's responsibilities are mostly in-house jobs, such as preparation of food, taking care of children, laundry, cleaning house and going to the market; they have a secondary role in rubber farming activities. Even though women have access to land, as in Jambi it is mostly a matrilineal system, women work predominantly in the wet paddy fields. Their access to education, technology, agricultural credit, and training in rubber is less than for men.

The division of work responsibility between husband and wife in a Jambi household depends on the economic condition of the family. In less wealthy families they work together for the survival of their family. There are some differences between women of wealthy households and those of less wealthy households. Women in wealthy households mostly do household work such as food preparation and taking care of children. Usually they have other sources of income such as a small shop in their house or other home based income generating activities. Their husband has a full time job as a teacher, a trader, in the government service or as a farmer. Some of the housewives are responsible for managing household spending (*uang belanja*). The other, usually less wealthy farmers' wife share the responsibility of jobs in rubber farming such as tapping, weeding and fertilizing. She also uses the opportunity to look for fuel wood for cooking. In this situation women are not only responsible for taking care of children and families but also in income generation and food production outside the home.

Women in the study locations usually undertake land preparation with help from the men, planting, maintaining and harvesting paddy rice and vegetables. When a crisis hits the area, women in Lubuk Kayu Aro are also responsible for earning income. From observation, most of those undertaking gold mining in the river are women. Women, as the men said, are more experienced at working in the river as they usually work in the wet paddy rice and do laundry in the river.

In some parts women and men complement their productive activities and household work. From interviews and field observations it is now appears common for women to accompany men in tapping latex from jungle rubber trees and women share the jobs of tapping, weeding and fertilizing. Men are more likely to be involved in the transporting and selling of rubber than women.

4.2.3 Sanggau District, West Kalimantan Province

1. *Geography*

The Indonesian province of West Kalimantan is the fourth biggest province in Indonesia and is located on the equatorial island of Borneo, covering an area of 146, 807 km^2 (7.53% of Indonesia). This province's location is on the equator; geographically this province is located in the west part of Kalimantan Island, in 2°08' -30°05' south longitude and in 108°0' -114°10' east longitude.

In general topography, West Kalimantan is flat with few hills or mountains, and it has hundreds of rivers. It is popularly known as a province of one thousand rivers and these that can function as the main form of transportation. The largest and longest river is Kapuas River (1,086 km). Part of the area is swamp and mangrove forest. The type of soils are predominantly red-yellow podzolic covering 10.5 million ha (17.28%), Orgosol, gley (14.7 million ha) and alluvial soil (2 million ha). This soil type is characterised by poor nutrients. Most of the land in West Kalimantan is forest (42.32%), and land dominated by Imperata cylindrica (34.11%), crop estates 1,574,855 ha (10.73%) and for settlement 0.83% (Kalimantan, 2008).

The population of West Kalimantan in 2006 was 4,120,000 people with a density of 28/km^2. The people now living in West Kalimantan are of various ethnicities owing to the transmigration programme that moved people from the more populated islands, mostly from Java Island. The population growth has also been influenced by the arrival of spontaneous migrants from other islands of Indonesia such as Java, Madura, Sumatra and Bali. The major ethnic groups of Dayak, Malays and Chinese are now mixed and have expanded and diversified through government and spontaneous migration.

The GDRP of West Kalimantan province in 2006 was IDR Rp.33.71 billion, the largest contributors were the agricultural sector (27.13%), trade, hotel and restaurant (22.69%), and industrial and manufacturing (18.53%). In the economic structure of this province, agriculture, including forestry and estate crops, was the leading economic sector. In other words dependence on natural resources was still high.

Table 4.5 Percentage distribution of Gross Domestic Regional Product (GDRP) by industrial origin in West Kalimantan (2004-2006)

Economic Sector		Year (%)		
		2004	2005	2006
1	Agriculture	27.48	27.03	27.13
2	Mining and Quarrying	1.25	1.26	1.23
3	Manufacturing Industries	19.92	19.03	18.53
4	Electricity, gas & water supply	0.65	0.65	0.61
5	Construction	8.19	8.33	8.55
6	Trade, Restaurant & Hotel	21.95	22.77	22.69
7	Transport & Communication	6.13	6.6	6.71
8	Finance, Leasing and Business Services	5.23	5.18	5.14
9	Service	9.22	9.15	9.42

Source: BPS-Statistic of West Kalimantan Province (Kalimantan, 2008)

The total area of smallholding rubber has increased every year as secondary forest land and land dominated by Imperata cylindrica is converted to several purposes such as rubber plantation.

Table 4.6 Area and production of smallholding rubber in West Kalimantan (2004-2008)

Year	Total Area (Ha)	Production (Tonnes)
2004	459,303	198,827
2005	468,736	222,413
2006	505,281	220,882
2007	522,182	221,382
2008	548,274	224,888

Source: BPS-Statistic of West Kalimantan Province (Kalimantan, 2008)

There are 12 districts in West Kalimantan, and Sanggau district is the largest area of smallholding rubber with 99,436 ha and the highest production of 48,554 tonnes in 2008 (Kalimantan, 2008). The district of Sanggau is located in the central area of Kapuas River and the north side of West Kalimantan, between 1° north latitude and 0°6’ south and between 109°8’ and 11°33' east longitude. The district covers 12, 858 km^2 or 13 % of the West Kalimantan province and administratively this district is divided into 15 sub-districts and 166 villages.

In the district of Sanggau, annual rainfall varies from 2500 mm to 3500 mm (155 days per year). Generally the day with the highest rainfall occurs in January and the lowest in August and the annual temperature is on average 26^0C. The dry season occurs from April to September; the rains start in September and become heavy from November until February.

The type of soil in Sanggau is dominated by red-yellow podzolic soils in hilly areas and alluvial in the valleys (MacKinnon et al., 1996). These soils' types have good physical characteristics but poor chemical characteristics and become acid. Rubber adapted to this area because rubber can still grow in poor soil.

This district had a population of 382,594 people in 2007. They live in villages which have 300 or more households in each village (91.57%). The population density is 30 people for each square kilometre. The growth rate of the population in 2007 increased 1.43%, from 0.85% in 2006. Most of the people aged 15 years and over worked mainly in the agricultural sector followed by the industrial and manufacturing sector (Kalimantan, 2008).

2. *Land uses*

During the period 1991 – 2000 there were considerable changes in the extent and quality of the natural forest. The total deforestation over this 9-year period was 42% or an average of 5% per year. The forest type most affected was high-density forest, which was reduced by 10,039 ha, or 44%. Low-density forest was also reduced by 37% from 1991. During the 1990s, the Indonesian oil palm area and production increased very rapidly in West Kalimantan (Potter, 2004).

The landscape of this area is dominated by logged-over forest, secondary forest and a mosaic of smallholder rubber with secondary forest re-growth. Large scale logging activities have been taking place at the expense of primary forest. At present, the forest only exists in the hilly area and is very limited. There are some timber plantations (HTI) operating in Sanggau, belonging to the Indonesian Government (PT Inhutani) and private companies. Smallholding rubber, oil palm plantations and Acacia mangium plantations, in extension, have gradually limited the forest area.

Table 4.7.Planted area and production of plant estates in Sanggau Regency (2007)

	Planted Area (Ha)				Production (tonnes)	Farmers (KK)
Plants	TBM	TM	TT/TR	Total		
Rubber	28,805	56,768	13,486	99,059	49,299	47,581
Oil Palm	30,313	112,315	2,849	145,477	1,145,592	35,269
Coconut	39	194	58,00	291,10	103,81	2, 413
Coffee	45	143.66	86.56	275.32	78.29	1,442

Note : TBM : Not Yet Productive, T M : Productive, TT/TR : Unproductive, KK : The Leader of Household
Source : (Sanggau, 2007)

Sanggau is the leading rubber district in West Kalimantan. Total production of rubber plants increased from 47,543.76 tonnes in 2006 to 49,299.11 tonnes in 2007, with the productive planted area increasing from 56,543 to 56,768 ha in 2007 (Kalimantan, 2008).

The other land use is oil palm plantation, as Sanggau is one of the districts in West Kalimantan that developed and invested in oil palm plantation. Oil palm is a new alternative for farmers in West Kalimantan. There are different situations regarding oil palm plantation in the study sites. The farmers in Kopar village started to divide their land for planting oil palm in 1997. The farmers joined the oil palm estate in different schemes. In general the farmers have to offer 7.5 ha of their land to a large private company for oil palm plantation, and they will get one to two ha of oil plantation to be owned and maintained when it reaches the stage for harvesting. However farmers still have to pay the loan for the establishment of oil plantation, and other costs such as fertiliser and pesticides.

3. *Economics*

Agriculture is the main sector of employment and the biggest contributor to the economic structure in Sanggau District. Industry and trading have been developed but are still below the contribution of the agricultural sector that consists of agriculture, forestry, crop estates and fisheries. The GDRP in 2007 was IDR 3.87 trillion; the biggest contributor was the agricultural sector (38.18%), followed by the industrial processing sector at 28.75 % and the trading sector at15.41 %.

Table 4.8 Percentage distribution of Gross Domestic Regional Product (GDRP) at current market prices by industrial origin of Sanggau (2006-2007)

	Industrial origin	**2006 (%)**	**2007 (%)**
1	Agriculture	37.71	38.18
2	Mining and Quarrying	29.2	28.75
3	Manufacturing Industries	13.84	14.37
4	Electricity, gas & water supply	0.24	0.25
5	Construction	3.68	3.75
6	Trade, Restaurant & Hotel	15.64	15.41
7	Transport & Communication	2.45	2.36
8	Finance, Leasing and Business Services	2.45	2.57
9	Service	7.46	7.61

Source: Statistics of West Kalimantan Province (Kalimantan, 2008)

4.2.4 Characteristic of the Villages

Four villages in Sanggau district were chosen for the case study namely Pana, Senunuk, Embaong and Kopar. Pana and Senunuk were used for developing the decision tree models and Kopar and Embaong for testing the decision tree models. Villages were selected based on criteria such as being under the RAS project. Characteristics of villages included in this study are described in Table 4.9 and 4.10.

Table 4.9 Summarised socio-economic conditions in Pana and Senunuk villages

	Locations for developing decision tree	
Characteristics	Pana	Senunuk
Topography	Piedmont/hilly poor soils	Peneplain poor soils
Land availability	Access to forest conversion, Plenty (owned/heritage), no certificate	Scarce, conversion to oil palm
Farming system	Extensive system, upland paddy, wet paddy, tembawang local and clonal rubber	Extensive system, upland paddy, local and clonal rubber and oil palm
Local rubber	Low productivity of jungle rubber, Imperata cylindrica	Low productivity, limited land
Distance to rubber location	Close (1-5 km)	Far (3-5 km),
Population density	Low	High
Ethnicity, religion	Dayak (Christian)	Dayak (Christian)
Social group	*Pengarih* (active); working together in farm/rubber activities	*Pengarih* (non active), farmer group
Road facilities	Half asphalted, gravel road, no road construction to rubber	Asphalted
Distance from district centre	9 km	20 km
Technologies introduction (Year)	Clonal rubber : ICRAF (2000&2005) and Dishutbun (2005), oil palm (2008)	Clonal rubber : ICRAF (2002), Dishutbun (2002), oil palm (1998& 2008)

Sources :(Mulyoutami, 2007) and field observation

Table 4.10. Summarised socio-economic conditions in Embaong and Kopar villages

	Locations for testing the decision tree model	
Characteristics	Embaong	Kopar
Topography	Peneplain	Piedmont/hilly
Ethnicity	Dayak (Christian)	Dayak (Christian)
Farming system	Extensive system, slash and burn for upland paddy, tembawang, local and clonal rubber and oil palm plantation	Extensive system; slash and burn for upland paddy, tembawang, local and clonal rubber oil palm
Local rubber	Low productivity, poor soil and *Imperata cylindrica*	Low productivity
Distance to rubber location	Close (1-5 km)	Close (3-5 km),
Population density	Low	High
Ethnicity, religion	Dayak (Christian)	Dayak (Christian)
Social group	*Pengarih;* limited farmers' groups	*Pengarih* (non active); farmers' group in Oil palm
Road facilities	Gravel road was not asphalted	Asphalted main road, access road at oil palm plantation
Distance from district	9 km	15 km
Technologies introduction (Year)	Clonal rubber : ICRAF (1996, 2002, 2005), local government (2005), SRDP (1988), oil palm (2008)	Clonal rubber : ICRAF (1996, 2002), local government (2005), SRDP (1988), oil palm (1998, 2008)

Sources : (Mulyoutami, 2007) and field observation

4. *Land system*

In the four villages the rights of indigenous forest village people in land use are based on customary rules called adat. These rules vary from village to village, but in general there are three main types of property tenure: common property rights; descent group common property rights; and, private property rights.

The land inheritance system is based on the same portion for women and men (daughter and sons), except for houses that are given to the son/daughter who take care of their parents. There are several ways for farmers to get land for their rubber garden including opening the forest, inheritance and purchase.

In the past, the farmers practised an agricultural system extensively based on rubber. Currently, the farming system in Sanggau, West Kalimantan is determined by the main farming activities namely t*embawang*, upland paddy, wetland paddy, oil palm plantation and rubber.

Tembawang

Tembawang or traditional mixed garden is one of the traditional systems that belong to Dayak in Sanggau. The main goal of *tembawang* is to establish fruits garden and woody trees together in one area that can fulfil the needs of people. Tembawang can be categorised as traditional complex agroforestry (Michon and de Foresta, 1995; Wulan et al., 2001). The components of tembawang in Pana village are timber trees Meranti (*Shorea sp.*), fruits; *durian* (*Durio zibhetinus*), *jengkol (Archidendron pauciflorum), petai (Parkia speciosa*), *Tengkawang* (*Illepe nut; Shorea macrophylla*) and also rubber trees in one location. *Tembawang* may be individual, family or communal (*tanah adat*). People in this area protect *tembawang* by establishing some rules such as making it prohibited to earn money by selling the woods without permission from all members of adat. Cutting trees still can be allowed but only for non commercial purposes such as building their own house. Fruits in *tembawang* especially durian may be owned by all members, but should be divided fairly for all members. They will give same amount of durian to every member of the group and members of the group have their own right to consume or to sell their durian fruit. *Tembawang* is important in terms of conservation, and the social and economic welfare of Dayak people.

Upland paddy

In this system after land clearing by slash and burn lands is planted in rice for three months, and after harvesting most of the farmers establish jungle rubber with unselected local rubber seeds. The farmers plant *pulut* paddy (glutinous rice/sticky rice) in the upper land (*ladang*). This paddy is the main material for making traditional drink (*tuak*; wine) that has an important role in traditional ceremonies.

Wetland paddy (sawah)

Sawah or paddy cultivation in the lowland with irrigation is an important farming system and is the main system to fulfil the need for rice for daily intake by traditional Dayak. In the past, the farmers usually kept paddy rice, as it is a symbol of wealth. However, in some villages such as Kopar and Embaong, most farmers buy rice from the market and are gradually abandoning the cultivation of wetland paddy. This is probably because land with irrigation has become smaller and scarcer. They still keep the upland paddy for their cultural ceremonies.

Oil palm plantation

The other land use is oil palm plantation, as Sanggau is one of districts in West Kalimantan that has developed and invested in oil palm plantation. Oil palm is a new alternative for farmers in West Kalimantan. There are different situations regarding oil palm plantation in the study sites. The farmers in Kopar village started to divide their land for planting oil palm in 1997.

Rubber

Rubber is the most common tree planted by farmers in Sanggau and has become the most important source of income. They planted rubber in the form of jungle rubber as in Jambi. The jungle rubber is essentially a secondary forest re-growth enriched with economically valuable rubber trees (Joshi et al., 2003) . The farmers planted unselected rubber seedlings following land clearing, normally through the slash-and-burn system. In the initial one to three years, upland rice and other annual crops may be grown between rubber trees. The observation found that rubber is usually planted randomly with no regular distance and at high density per ha compared to rubber plantation. After the rubber trees and other natural regeneration begin to affect the annual crops, farmers abandon these plots without further fertiliser or other input. Farmers usually do other jobs such as tapping other plots of old rubber or other farm or off farm income-earning jobs. The rubber trees continue to grow until tapping time and farmers return to the plots occasionally to keep the rubber trees free from competing vegetation, climbers and lianas. Farmers usually start to tap rubber 10 years after planting. Tapping starts later than for clonal rubber which can be tapped at an age of five to six years old. However this also depends on the management of the rubber garden.

5. *Labour system*

In Sanggau District, similarly to Jambi, there are three main labour sources in the farm labour system namely family labour, paid and collective labour. In the study area especially in Pana there is working together between farmers namely "*pengarih*". This collective action is practised as the farmers face shortage of labour. This system is basically for agricultural activities such as land clearing, planting and harvesting of upland and wetland paddy. The pengarih now also is applied for rubber cultivation, including intensive clonal rubber garden. The collective action usually is applied for land clearing, land preparation for rubber cultivation and for maintenance. This system helps farmers to face the problem of lack of labour. In this system each member of a farmers' group has obligation to help other farmers in rubber establishment and maintenance. In return each member has the right to ask other members to help in exchange for his work on other farmer's land. The other collective labour is "*gotong royong*", this may be applied in working together in the village such as renovation of village office, church, school, road village or other public facilities.

In maintenance of immature rubber, weeding is important in reducing competition for rubber and other crops or trees. As in West Kalimantan, aggressive *Imperata cylindrica* was become a problem, regular weeding is necessary. The manual system takes time and labour, therefore farmers are mostly using herbicides for weeding. The other operation is fertilising, which has to be done regularly every three months for the first three years of establishment of clonal rubber. Most farmers use family labour or paid labour for weeding and fertilising.

6. *Tapping and Marketing*

Rubber farmers tap their rubber trees almost every day - normally five to six days a week. However, usually they reduce the intensity of tapping during the rainy season, and planting or harvesting season, and during social, cultural and religious festivals. Family members are the main labour for tapping. There is also a share tapping system which is usually based on 70:30 scheme, that means 70% of the yield goes to the tapper and 30% to the owner. Most of the farmers sell the latex directly to a middle-man trader (*toke getah*) and the other, usually wealthy; farmers sell the latex to the factory. Auction is not available in the marketing system in West Kalimantan.

4.3 Selection of Sample Respondents

The samples for this research were the heads of rubber farmer households who owned or managed rubber agroforestry. The list of respondents was provided by different sources including ICRAF, village leaders, extension workers and farmers' group leaders. ICRAF provided information on farmers who had participated in the RAS project and all of the farmer participants were categorised as adopters. The non project participant respondents who could be adopters or non adopters were chosen based on the information from the participant farmers and farmer group leaders. The sample was chosen to be as representative as possible of the population of rubber farmers. They were selected to represent the diversity of farmers' conditions such as different sizes of rubber plantations, ages, range of income, type of main job, level of education and variety of physical features such as percentage of slope of the rubber plantation.

The respondents were selected by using purposive sampling. This method is applied for identifying specific cases for in depth investigations (Neuman, 2000) and is based on the "knowledge of a population, unit of analysis and the purpose of the study" (Babbie, 2004, p. 183). By using these methods it will be possible to identify a variety of responses from a population. The selection of the sample included rubber farmers who had, and had not used the clonal rubber in their rubber agroforestry system. As a result, the analysis could cover and explain the different decision process of both adopter and non adopter farmers.

The sample size has to meet the requirement for the development of a tree-decision model which is around 20-30 respondents per village, or 90-120 for regional areas (Gladwin, 1989). From the literature there were examples of the number of respondents needed for developing and testing decision tree modelling (see Table 4.11).

Table 4.11 Number of respondents for developing a decision tree and its testing

Sources	Sample for decision tree model	Sample for testing model
Fairweather (1992)	25	-
Jangu (1997)	25	-
Fairweather (1999)	43	-
Wurjanto (2001)	146	161
Gladwin (2002)	121	-
Darnhofer et al., (2005)	21	65
Morera and Gladwin (2006)	61	-
Sambodo (2007)	130	30

The total number for this study was 229 respondents in 8 villages in two provinces. The respondents were chosen with the composition in table 4.12. This sample was also able to be used for statistical analysis purposes.

Table 4.12 Composition and number of respondents for developing a decision tree and its testing

Locations	Decision tree	Testing Decision tree
Bungo District, Jambi		-
- Rantau Pandan (RP)	31	-
- Sepunggur (SP)	30	-
- Lubuk Kayu Aro (LKA)	-	25
- Pulau Temiang (PT)	-	35
Sanggau, West Kalimantan		-
- Pana	26	-
- Senunuk	22	-
- Embaong		30
- Kopar		30
Total	109	120

All respondents’ names and addresses were undisclosed and only the number of the respondent was used as identification of each respondent from the group of adopters and non adopters and locations.

4.4 Data Collections Methods

The process of the study is shown in the figure 4.3 below.

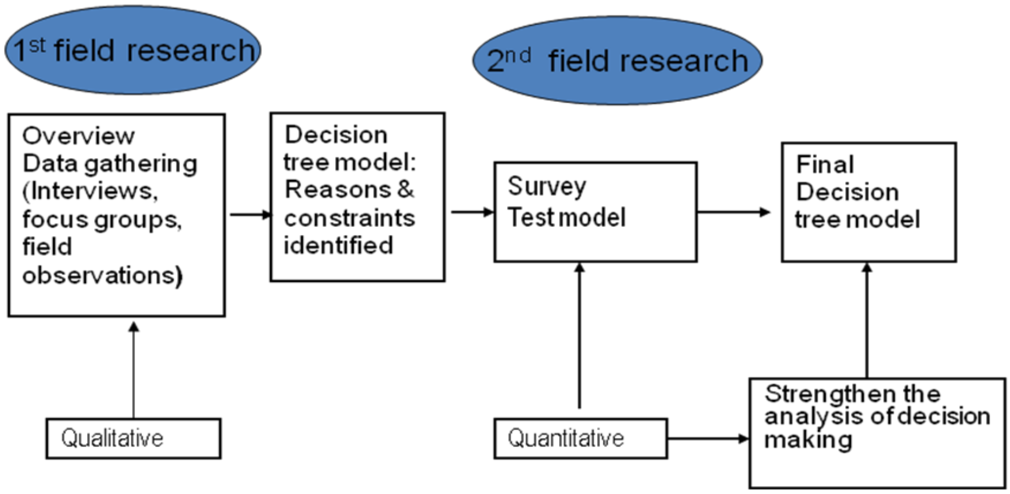


Figure 4.3 The process of the research

The main research method consisted of unstructured interviews and structured questionnaires in the selected locations. Combinations of different types of interviews for collecting data included:

a. Unstructured ethnographic interviews for eliciting farmers' decision criteria, decision path and decision process of the adoption of clonal rubber
b. Structured questionnaires of the background of farmers in order to gather information conditions of the farmers' households and for confirming the farmers' decision criteria
c. Other procedures for data collection were focus groups and field observation

Data collection was held in two periods; the first field research was in Jambi and West Kalimantan in February to June 2008 and the second field research was in these same two provinces but different villages in February to April 2009. The first field research was mainly for the development of decision tree models and the second field research was for testing the decisions tree.

All questionnaires were prepared in English and later were translated into Indonesian Language (*Bahasa Indonesia*) to deliver to the farmers. I developed the questionnaire in English and I received professional help in question construction from my supervisors at the University of Canterbury and a specialist in questionnaires at World Agroforest in Bogor (ICRAF). Then, I translated and constructed the questionnaires into *Bahasa Indonesia* (Indonesian language), also with help of the ICRAF expert. Therefore this enabled me to pick up possible problems which might not be revealed in a pre-test with respondents. Pre-testing is important part of the questionnaire construction process and is crucial for recognizing questionnaire problems (Ron, 1998). The questionnaires in *Bahasa Indonesia* then were tested with the farmer respondents to check that the ideas and questions were understood by respondents in the same way that I intended. Questions that were too complicated or had possibilities for misinterpretation by the farmers were restructured. I also changed some words to the local language so that they could be more understandable by the farmers. Therefore data collection was more efficient and accurate.

Ethical aspects of the field work including all interview procedures and questionnaires being discussed in detail with my supervisors. These included applying the principle of anonymity, confidentiality of the sources of information, and security of data during and after the interviews. All procedures and questionnaires were approved by the Human Ethics Committee of the University of Canterbury in February 2008. Permission to undertake the research was received from the Government of Indonesia and the International Centre for Agroforestry Research (ICRAF), in Bogor, Indonesia, provided support and was a host institution during field research.

4.4.1 Farmers' Background

To get the background of respondents, the survey was administered to farmers to collect household information related to rubber management. The questionnaires were applied after the semi ethnographic interviews were finished. This was mainly because the background data contained some personal details and so only sought after we had come to know one another in informal conversation. The data collected included:

a. Farmers' characteristics; such as age, gender, family size, education, occupation, income, land size, rubber farming experience.
b. Farm practice; such as farming objectives, labour system, marketing product and their access to production facilities such as market, fertiliser and pesticides
c. Farmers' management of information and extension activities; such as farmers' methods of keeping farm records, availability of sources of information, farmers' participation in farmers' group, relationships with other farmers in terms of exchange of information and how they influence one other in decision making.
d. Institutional factors; such as information access, extension contact, role of local government, NGOs and participation in training

4.4.2 Developing the Decision Tree Model

In the first field research period, an unstructured interview based on ethnography was used for eliciting and confirming the criteria used by farmers in their decisions regarding the adoption of clonal rubber. After receiving permission from the village leader, I visited individual rubber farmers in the village for interviews. Data were collected by face-to-face interviews with the household leader as the main decision maker. Interviews were established in different locations and according to the time availability of the farmers and were carried out in the farmer's home and mostly accompanied by his wife, other family members or neighbours. Sometimes with the agreement of the farmers the interview was carried out in the field during break time from tapping, or in the small shops after working hours. In Jambi the best time for an interview was on Friday, as most of the farmers are Muslim and Friday is a holiday. Before and after night time prayer were the best times for interviews as it was easier to meet respondents. In West Kalimantan as most of them are Christian, the best time for interviews was on Sunday after prayer, or after working hours or during the night.

Figure 4.4. Interviewing respondents in their rubber garden and small shop in the village

Most of the respondents were adult males and the household leader, except for a female widow. Traditionally, in Jambi and West Kalimantan, most of the decisions in the family are made by a male as a leader and, in addition, having a visit or a chat with a female/wife in their house is prohibited without permission, or unless she is accompanied by her husband or another adult male or family member. However, during the interview with the husband, his wife was also encouraged to participate and share her responses to the interview.

At the beginning of the interview I introduced myself, and the objective of the research, as well as asking permission to record the entire interview. The interview was informal which allowed the farmers to share freely their own opinions and feelings. This followed the suggestion that an ethnographic interview is similar to an informal conversation and the respondent should be allowed to talk without restraint (Spradley, 1979). However in some circumstances the interview became stuck, so some highlight points were used as guidance. This guidance was used to highlight the decision criteria mentioned by farmers so that the data would be eligible for the construction of the decision tree model. These are some examples of guidance for the informal interview:

a. How important is rubber for the farmers?
b. I am interested in your explanation about the application of clonal rubber in your jungle rubber. Tell me about how you became interested in clonal rubber?

c. How did you know about the advantage of clonal rubber?
d. Is it difficult if I want to learn about and apply clonal rubber? Why?
e. Could you describe the benefits of the jungle rubber?
f. Could you describe your opinion of the clonal rubber?
g. Could you give an example of your experience if you found difficulty in planting clonal rubber?

The questions generally covered the level of knowledge of farmers regarding traditional and new rubber systems, their knowledge of clonal rubber and components related to their rubber garden management, their experience and their response to the introduction and application of clonal rubber to their traditional system. The procedures basically followed Gladwin's (1989) book of ethnographic decision tree modelling. The farmers usually expressed their decision by explaining the process from the beginning of learning about clonal rubber until the decision to adopt or reject the clonal rubber. Then the interview continued with confirmation and more emphasis on the discussion on the possible decision criteria mentioned by the farmers.

Once the semi-ethnographic interview was finished, the survey of their background and related information on their rubber management was continued with. The interview took approximately one hour thirty minutes to two hours for each respondent. In the end, I concluded the interview and thanked the respondents for their valuable participation. After interview the farmers had an opportunity to discuss their problems in their rubber gardens with technical staff from ICRAF.

4.4.3 Testing the Decision Tree Model

The ethnographic decision tree models of Jambi and West Kalimantan should be tested to measure the accuracy and predictability of other groups of rubber farmers. The model should be tested against chosen data collected from other individuals in the same population (Gladwin et al., 2002).

The procedures of the testing decision model followed Gladwin (1989 p.45-57). The procedures are:

1. ***Questionnaires***

In this second field research, the questionnaires based on the reasons and constraints presented in the decision tree were administered to the respondents. The questionnaire was mainly close-ended in the format of a "yes" and "no" answer following the procedures of the book of ethnographic decision tree modelling by Gladwin (1989). However, in the interview sometimes I asked them for additional information, for confirmation of their responses of "yes' and "no" and if they had other options. The interview also collected household information including farmers' characteristics, farm practices, socio-economic factors, institutional factors and other relevant information.

2. ***Respondents***

The process of choosing respondents for testing was the same as in the first field research. All respondents for the testing in these villages were not involved in the first interview. The decision tree model that was developed from the first interview in Jambi and West Kalimantan was tested on other groups of farmers in two villages, namely Pulau Temiang and Lubuk Kayu Aro in Jambi and two villages, namely Embaong and Kopar village in West Kalimantan.

3. ***Delivering the questions and recording the responses***

The interviews for the test were carried out by the researcher and two field assistants who had experience in surveys and were familiar with people in the area. I did interviews usually during the afternoon when farmers were going back from their rubber garden or during the night after dinner. Interviews were carried out individually, however sometimes the respondent was accompanied by his wife, family or neighbours. It was difficult to meet and interview farmers during the day as most of them were in their rubber garden or doing other activities.

However in general, farmers were still keen to answer and respond to the questionnaires. In the interview, collecting information about the time they heard about the introduction of clonal rubber in the past was emphasised. Some farmers refused to become respondents as they lacked confidence; they had no time or were not at home when we came to their house. In the end 121 respondents in Jambi and

108 respondents in West Kalimantan were interviewed and their responses were used to test the decision tree modelling.

4.4.4 Data Collection for Quantitative Modelling

Data for the logistic analysis was collected in the first field trip and second field trip. The data including socio economic background were collected from individual farmers on their adoption or otherwise of agroforestry on their plots. The respondents were adopters and non adopters, in four locations in Jambi and four locations in West Kalimantan. A total of 233 farmers were included in the survey; 229 respondents were involved in development of the decision tree model and testing, and 5 respondents that were only suitable for logit model only. The results were used for this logit analysis.

A focus group approach was also used to collect information in depth through discussion on the issues related to the adoption of agroforestry technology on their lands. Focus group interviews are any discussion held between a researcher and more than one individual. This is also called group interviewing and resulted in qualitative data. It may obtain information that would not emerge from the individual's interview (Babbie, 2007). In this focus group, a small group of rubber farmers are guided by a moderator who facilitates discussion, dialogue and interaction. The main objective of the focus group is to confirm decision criteria and constraints in the adoption of clonal rubber and the importance of each decision criterion from their opinion and perceptions. This is important to support, confirm or add to the information that has been found in the individual interview to build the decision tree model.

Focus groups were held in the two locations in Jambi namely Pulau Temiang Village and Lubuk Kayu Aro Village as well as two villages in West Kalimantan namely Kopar and Pana Villages. In these focus groups, participants were around 5-10 rubber farmers. In the beginning I delivered the questions to the group on what factors are important in the adoption of clonal rubber from their point of view. Next, I let them discuss and come up with agreement. The main questions were on the factors that motivated them to apply clonal rubber and the factors that became constraints. In the beginning all farmers were encouraged to mention all the factors in planting clonal rubber from their own experience, and then in the second step they grouped all similar factors into key terms. In the end, they had a discussion and arranged the ranking of factors from very important to less important. Each of the farmers gave his opinion by weighing each factor by putting in a number of seeds. The number of seeds was calculated in the end and the more seeds in the factor the more important this factor was in their decision.

The other method used was field observation. This observation is additional information to the ethnographic interview (Spradley, 1979) and is the best way to observe the respondents' behaviour (Gladwin, 1989) in rubber practice. This field observation included accompanying farmers in their activities in their rubber garden, from the beginning of the day when they were going to their rubber garden, tapping, replanting, until transporting the rubber ready for sale.

Nursery production was observed, for commercial purposes or for fulfilling their needs. In Jambi there were three nurseries visited, including private nurseries that provide clonal rubber to sell. In West Kalimantan there were several nurseries visited that included nurseries belonging to private farmers to fulfil their needs, nurseries in the farmers' group and commercial nurseries in Bungo and Sintang Districts. This observation is to show the condition of availability and prices of clonal rubber seedlings.

Field observation also included the marketing system in Jambi and West Kalimantan. In Jambi I visited the centre for the auction of rubber to see the process of marketing rubber by farmers, in the level of sub district and district. I saw the process of the trade of rubber from farmers to the middleman. In West Kalimantan which has no auction observation was carried out at the level of middleman and big buyer in the market.

Information was also gathered from relevant government departments, local government, universities and NGOs (Non Governmental Organizations) involved in the project. Interviews were carried out with extension workers, field staff of ICRAF, Dishutbun and village leaders. The data collected by different methods were then documented in the format of written notes, field notes, audio taped records of interviewed conversation, photographs, maps and observational checklists.

4.5 Data Processing and Analysis

4.5.1 Decision Tree Modelling

Background data from the two locations were analysed using descriptive statistics to provide a general picture of farmers' backgrounds and locations. Data are presented in the first part of the results chapters (chapters 5 and 6) as tables and graphs to give a general view of the condition of the respondents.

Data gathered from the semi ethnographic interviews were used to build a hierarchical decision tree model. Each recorded interview was transcribed into a written transcript then used and elaborated with the detail from other sources of data such as field notes and field observation. Quantified data were transferred to Excel.

After each interview was examined, a summary of the key/main points that may represent decision criteria and constraints in the adoption of clonal rubber was determined. All the responses of respondents were classified into a number of key or general terms. The main reasons and constraints were highlighted and put in summarized form. All detailed information given by respondents was examined in order to develop decision criteria. This was followed by the steps to model respondents' decision processes by Gladwin (1989 p.21-15) and Sambodo (2007 p.153) to establish decision tree models. The stages are as follows:

a. The decision was defined as a decision to adopt or to not adopt clonal rubber.
b. Then, the decision criteria as key terms were put in the main decision tree and constraints in the branch or branches, with each domain branch leading to a decision, to adopt or not adopt clonal rubber. If there were more criteria they were followed in the next branch or branches.
c. The main decision tree and the branches were checked for a logical decision making flow and checked to determine whether more branches (more constraints) were required before the final decision;
d. A meaning and explanation of the decision tree model were provided.

In this study there will be two main decision tree models for the two locations in Bungo district, Jambi provinces and Sanggau District West Kalimantan. The results of the development of the decision tree models are shown in the chapters 5 and 6.

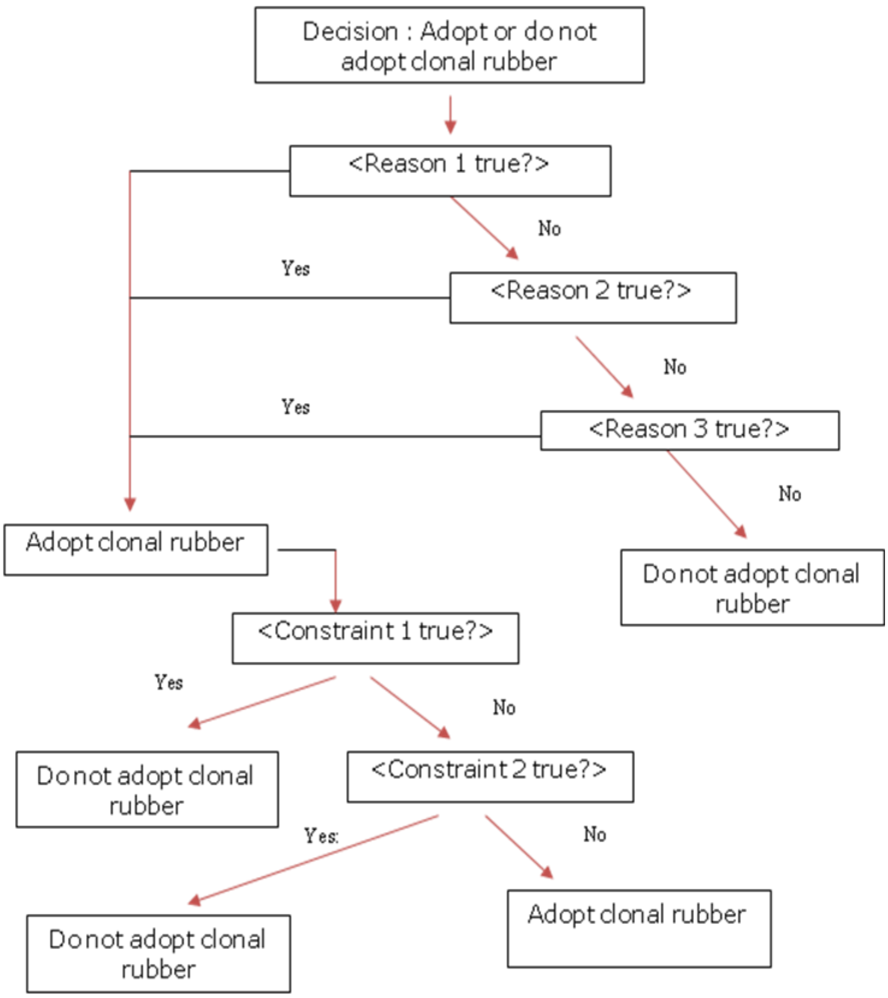


Figure 4.5 Example of decision tree development (modified from Gladwin, 1989a, p.42)

4.5.2 Testing the Decision Tree Models

Testing the decision tree models was the next step in the development of the decision trees. Data from the interview results which were mainly the answers to the ‘yes’ and ‘no’ questions were gathered and summarised. Further, based on the procedures of the testing decision model by Gladwin (1989a p.45-57), the path for each respondent was followed; some respondents stopped at the specific constraints and others still went through to pass other decision criteria and constraints until the end of a decision branch and final decision choices. Further, the number of respondents in each end of the branches (when decisions were made) was calculated to count the success rate of the model.

The success rate of the model can be counted by using the formula below:

$$\text{Success rate} = \frac{\text{total number of successes}}{\text{Total number of cases}} \times 100\%$$

The decision tree model will work well if it can predict a high percentage of what people choose in other villages/locations. The percentage of predictability is counted by the ratio of correct predictions of farmers' choices divided by the total number of farmers who made their choice in the decision. The application of this model in various studies has showed that the decision model may successfully predict 80-90 percent of the choices of the individuals in the group (Fairweather, 1992; Gladwin, 1989; Jangu, 1997; Murray-Prior, 1998).

4.5.3 Quantitative Model

1. *Descriptive analysis*

Descriptive statistical analysis was used to explore the data collected from the two main locations to summarise and to describe the basic features of the data. This method of analysis provided statistics of some general observations about the characteristics of the sample such as the number of respondents, whether they were female or male and the age range. It did not show the relationship between the variables but was useful to provide guidance for quantitative analysis. In this study this method was used to show the frequency distribution of the variables of adoption for different categories of adopters and also to measure the central tendency and variability including mean, median, standard error, the range, standard deviation and variance. The result relating to characteristics of respondents is shown using Analysis of Variance (ANOVA). This analysis was used to test the difference between two or more means for dependent continuous variables such as age, land, labour, income and experience.

2. *Variables*

Data both qualitative and quantitative were collected from eight villages in two study locations using structured questions and were transferred into Excel spreadsheets. By using Excel, non-continuous (dichotomous) and continuous variables were re-coded to fit the analytical software requirements (Coakes et al., 2009) for interpretation. For binary or non-continuous variables, responses were obtained from what farmers stated about the adoption of clonal rubber and were only “No” and “Yes” responses. In the analysis, some of these categories were reduced to binary variables (for example in membership of farmers’ groups; 1 = member, 0 = non member).

Table 4.13 Summary of definitions and descriptions of variables used in the logit model

No	Variable	Type of Variable and Description
1	DECI (Decision)	Dependent variable is the decision to adopt clonal rubber, categorical; 1 = If farmers have adopted clonal rubber, 0 = if farmers have not adopted clonal rubber
2	AGE	Continuous age of respondent
3	EDUCATION	0= Elementary school, 1=Intermediate 2= high school 3=University degree
4	FLAB (Family Labour)	Number of family members aged more than 15 years and working in the rubber garden
5	EXP (Experience)	Length of experience (years) in rubber management based on the first time of planting rubber independently
6	LAND (Land size)	Size of land holding continuous (Ha)
7	INCV (Incentives)	Have incentives [1= Yes, 0=No]
8	OFJB (Off farm job)	If the farmer has off-farm income sources [1=Yes, 0=No,]
9	INC (Income)	Continuous rate on income/year (IDR) Income is based on accumulation of income from rubber production and income from other sources
10	FMG (Farmers’ group)	If the farmer belongs to a farmers’ group [1=Yes, 0=No]
11	DEMO (Demonstration plots)	Has seen demonstration plot or other farmers’ clonal rubber garden [1=Yes, 0=No]
12	TRNG (Training)	If the farmer had training in clonal rubber from ICRAF or other institutions [1=Yes 0=No,]
13	LOC (locations)	Location of study; 0=Jambi, 1= West Kalimantan

As reviewed and discussed in Chapter 3, there were many studies; in economic, sociological and anthropological related to technology adoption in agroforestry technologies, including adoption of rubber agroforestry in different countries (Adesina et al., 2000; Cramb, 2000; Jera and Ajayi, 2008; Mercer, 2004; Neupane et al., 2002; Salam et al., 2000). In this study the potential variables used to explain the adoption of agroforestry technology clonal rubber were compiled from the various sources. Then, the potential variables that influenced the adoption of clonal rubber were developed from the interviews for the decision tree and the survey for the test of the decision tree in four villages in the two main locations. These variables are summarised in table 4.13

3. *Logit model analysis*

The correlation analysis is used to examine the linear relationship between two variables and to show whether and how strongly pairs of variables are related. The correlation is one of the most useful statistics as correlation may describe the degree of relationship between variables (Coakes, 2007; Kinear and Gray, 2010; Trochim, 2006).

The logistic regression is used as it provides a useful means for modelling the dependence of a binary response variable on one or more explanatory variables that can be categorical or continuous (Bewick et al., 2005). The variable is equal to 1 if the farmers adopt clonal rubber and 0 if they don't adopt. Their choice depends on some factors or characteristics which are categorised as independent variables.

In this logit model, R^{i} is represented as a dichotomous variable that equals 1 if the farmers adopt clonal rubber and 0 if they do not adopt clonal rubber. The probability of planting choice, $Pr(R_i = 1)$, is cumulative density function evaluated at Xi b, where Xi is a vector of explanatory variables and b is a vector of unknown parameter (Johnston and DiNardo, 1997).

Decision to plant clonal rubber =

$$\Pr(R_i = 1) = \frac{\exp(Xi\beta)}{1 + \exp(Xi\beta)}$$

The estimation form of the logistic transformation of the probability of the farmer's choice to plant clonal rubber $\Pr(R_i = 1)$ can be represented as:

$$\ln\left[\frac{P_i(R_i=1)}{1-P_i(R_i=1)}\right] = \beta 0 + \beta\mathbf{1}\,X\mathbf{1} + \beta 2X\mathbf{2} + \beta 3X\mathbf{3} + \beta 4X\mathbf{4} + \beta 5X\mathbf{5} + \beta 6X\mathbf{6} + \ldots$$

In order to estimate the parameters of the variables influencing farmers to plant clonal rubber, a maximum likelihood estimator is used. The estimated model can be represented by the equation:

$$\ln\left[\frac{P_i(R_i=1)}{1-P_i(R_i=1)}\right] = \beta 0 + \beta_1(Age) + \beta_2(Educ) + \beta_3(farmLabour) + \beta_4(Exp) + \beta_5(Land) + \beta_6(Incentive) + \beta_7(Income) + \beta_8(OffFarmJob) + \beta_9(FarmGroup) + \beta_{10}(Demo) + \beta_{11}(Training)$$

Usually in the use of logistic model, coefficients are tested for significance for insertion or elimination from the model by using statistical tests such as a Wald test and likelihood ratio (Bewick, 2006). In this study, the Wald statistic and the likelihood test were used to assess the significance of the variables.

4.6 Summary

This chapter provided a background description of the study area, an explanation of how, and what data was obtained, and analytical methods used to obtain results for the thesis. Presentation of the location of the study covered the general situation of geographic, biophysical and population data related to the role of rubber production, management and condition of rubber in provinces and districts. It is followed by a description of each village chosen as a study site for this research.

The main methodology for data collection for this research was face-to-face structured and semi-structured interviews. The main data in this research were: background data, data for developing the decision tree model, data for testing the decision tree model and data for developing the quantitative model. Background data including demographic, agro climatic, socioeconomic and institutional data were gathered using structured interviews. The data for developing the decision tree models were gathered using unstructured interviews to elicit farmers' decision criteria, constraints, and decision paths to identify different adopters' and non adopters' behaviours. The results were the farmers' qualitative responses to the interview and construction of decision tree models. Data for developing the quantitative model were collected in the two phases of field research. The data included age, family size, occupation, education, labour availability and farm size and farmers' group membership to provide various data for statistical analysis of the significance of factors influencing the adoption of technology.

The analysis of background data used descriptive statistics and the result was to show the general background condition of the respondents. Further, the qualitative data were used for the development of the decision tree model for the adoption of clonal rubber. After the decision tree models were built, the next process was to test them by delivering structured interviews to respondents. Surveys that had been used in the data collection for the development and testing of decision tree models also continued to be analysed using quantitative model logistic regression.

The different methodology of data collection and different types of data (qualitative and quantitative) may answer the objective of the study and enrich the discussion. The result of the data analysis will be presented in the next four chapters (Chapters 5, 6, 7 and 8).

Chapter 5 The Decision Tree Model for Jambi

5.1 Introduction

This chapter presents the socioeconomic characteristics of respondents based on interviews, secondary data and field observations. The characteristics of rubber management are highlighted also as these have an important role in the decision making of the rubber farmers. Next, the results from the ethnographic interviews are summarised and presented in a decision tree format. The decision tree model represents the decision making steps and the decision criteria that the farmers use. The results of the tested factors of the decision tree are also presented and discussed with relevant theoretical and empirical justifications.

As mentioned in the review, the ethnographic decision tree model can be used to analyse in detail each of the decision criteria and constraints in the adoption or rejection of clonal rubber. The analysis follows the sequence of decision criteria from the decision tree, such as why do they believe or not believe in clonal rubber? How do incentives become important factors in making decisions? The results from the decision tree combined with evidence such as quotes of responses from respondents and other information support decision factors. This section mainly tries to answer the research questions of why farmers adopt or do not adopt clonal rubber.

5.2 Characteristics of Respondents

5.2.1 Socioeconomic

The characteristics of respondents in the study sites are: age distribution, level of education, land ownership, experience in rubber farming, family size and gross annual income rates. These are presented in Figure 5.1.

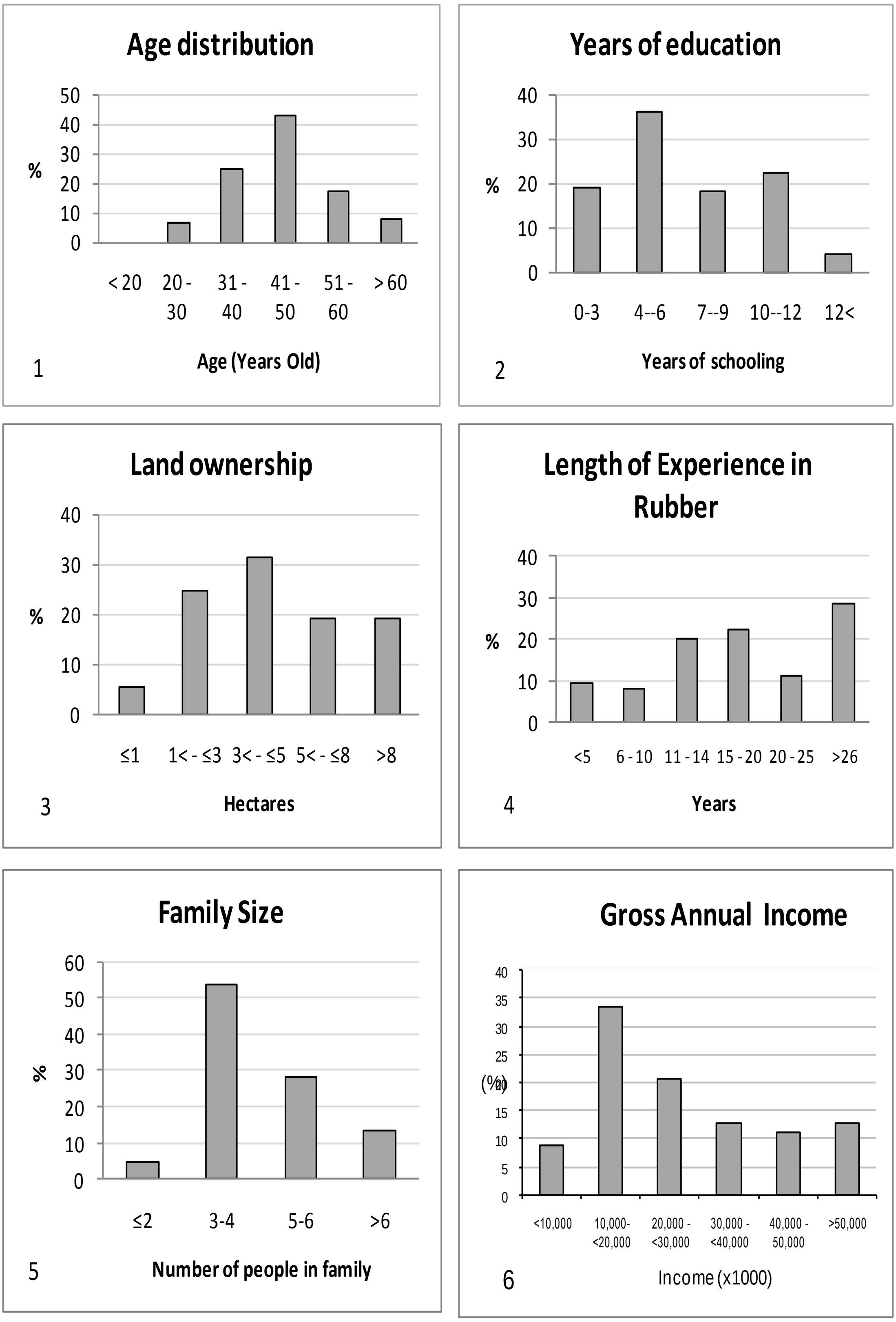


Figure 5.1 Graphs 1-6: Socioeconomic characteristics of respondents in Jambi

The number of respondents totalled 121 rubber farmers in four villages namely: Rantau Pandan, Sepunggur, Pulau Temiang and Lubuk Kayu Aro. These villages were under the administration of Bungo and Tebo Districts, Jambi Province. The majority of the respondents in this research were between 31-50 years of age (70%). There was a range of ages; the oldest respondent was aged 70 years old and the youngest was 22 years old. Most of the respondents were married except for three respondents in Sepunggur village who were widowers. The average household size of the respondents was four persons (55%); husband, wife and two children. Most of the respondents' families lived in single households; only a small number lived together with their extended families. The number of family members who were working in the rubber garden was limited to the head of the family and his wife only (61%). The reasons for this, as mentioned by the respondents and as shown from the data of the ages of family members were: their children were either under productive age or in school, or they had chosen another job after graduating from school. Generally, young farmers start to manage their own rubber at the age of around 20 years or after getting married. Before this age they usually follow their parents working in the rubber garden and have experience in working in a traditional rubber system. As the average respondent's age was 31 to 50 years old, most of the respondents had experience in the rubber garden for ten years or more. This experience may have influenced their perception of introducing clonal rubber to their land.

In terms of land, 60% of the respondents were farmers with fewer than 5 ha of rubber garden land. On average, the rubber gardens belonging to respondents from Rantau Pandan and Lubuk Kayu Aro villages were larger than in the two other villages (Pulau Temiang and Sepunggur). The farmers in Rantau Pandan and Lubuk Kayu Aro villages still had the possibility of extending their rubber gardens as they had access to more forest land although the locations are far from their village. In education, most of the respondents had only primary level schooling (55%). In the past the primary education system was for three years only and most farmers in the 55 years old or older were in this category. Only 5% of the respondents had a higher education and most of them were teachers or local civil servants.

Figure 5.1 also shows the average annual gross income of respondents. This annual gross income was mainly based on the average yield of rubber that the farmers get every month without extraction of expenses. The average gross annual income of respondents was IDR (Indonesia Rupiah) 30,000,000 (US$ 3,000). In some cases, the annual income was less than the average income; all farmers in this category have less than three ha of rubber area. Some of the farmers with an annual gross income of more than IDR 50,000,000 were teachers and rubber traders with a large rubber area. Some of the farmers have an additional income from other sources such as gold mining, animal husbandry, running a small shop or a small restaurant at home. Respondents' income, type or income sources including farm and off farm job may affect the decision of farmers to adopt new technologies for their land.

5.2.2 Rubber Management

Characteristics of the traditional rubber system in Jambi can be identified from such factors as: farmers' objectives of the establishment of a rubber garden, labour systems, marketing systems and information system.

1. Objectives of farmers

From the interviews, it can be determined that the main objectives of the establishment of a rubber garden vary (Figure 5.2). Most of the respondents (75%) stated that their main objective for establishing their rubber garden was to provide their primary source of income. That means rubber has an important role for the farmers. Only some respondents (20%) had the objective of planting rubber as a secondary form of income. Most of them had off farm jobs such as: teaching, trading, working for local government, working for a private company or running their own businesses. These respondents had a regular income and used the rubber garden to supplement this. The farmers maintained their rubber gardens before starting or after finishing their main job each day or paid labourers to do the rubber garden work.

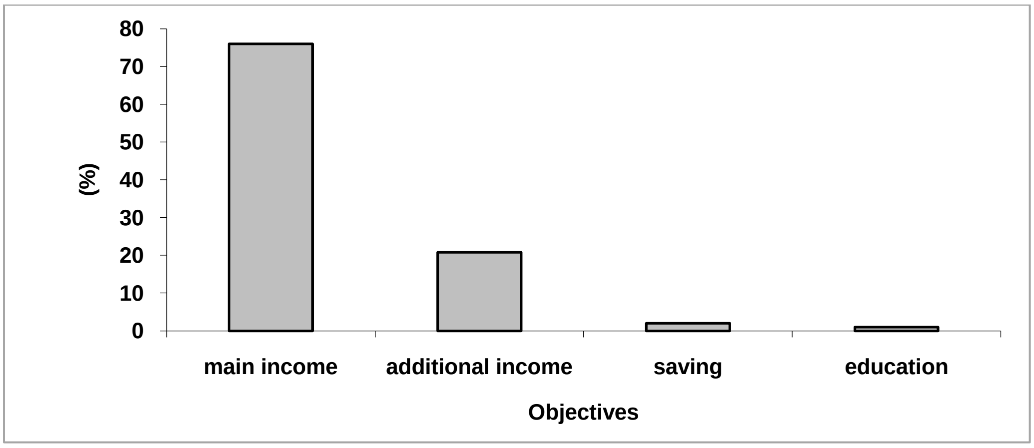


Figure 5.2 Farmers' objectives in rubber planting

The remaining respondents' objectives of establishing rubber garden were for saving, paying for their children's schooling or saving for a pilgrimage to Mecca (one of the Muslim rituals). Some farmers also mentioned that the rubber garden was not only for their main income source but also can conserve and maintain the land that they inherited from their parents.

2. The Labour system

Labour was needed during the main stages in rubber garden activities, namely establishment, maintenance, tapping and marketing. From the interview, it was found that the farmers work with their family or they pay labourers to establish and maintain their rubber garden. The farmers who have no capital work with their family and extended families. The farmers who have no time as they have another job and wealthy farmers with large areas of rubber land mostly pay labourers.

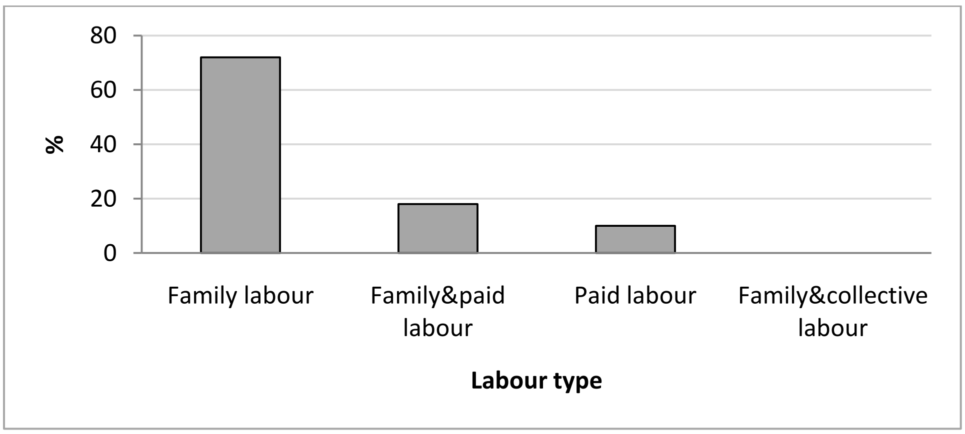


Figure 5.3 Types of labour in the rubber garden

As can be seen from Figure 5.3, the main source of labour is family member (70%). Most of the work in the rubber plantation was completed by the farmer, his wife and his family (son, daughter or son or daughter in law). However in some cases other sources of labour were used during maintenance and tapping of the rubber garden especially for hard work stages such as clearing and fencing, or when they have no time as they to do other agricultural work. They combine different sources of labour such as temporary paid labour. The rubber farmers who fully depend on paid labour (10%) mostly have off farm job or managing rubber was not their main job. These farmers generally were traders, government officers and teachers or other jobs in the city.

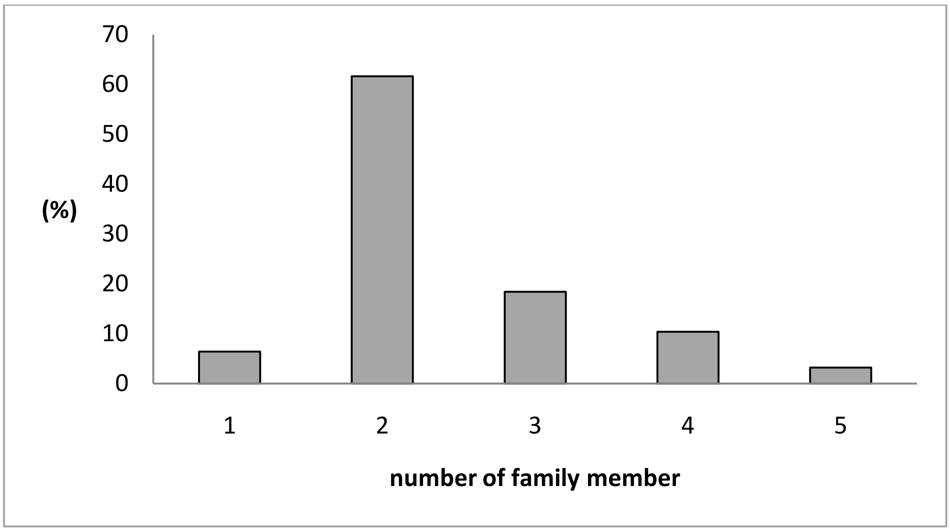


Figure 5.4 Number of family members working in the rubber garden

The availability of family labour may be insufficient to fulfil all the labour demands of a rubber garden. Eighteen percent of respondents combined family and paid labour, usually if they were busy with other peak agricultural activities, but usually only temporarily and only for certain jobs.

3. *Sources of information*

Information was one of the important factors in the diffusion and adoption of technology. In this study farmers in Jambi were asked if they were using clonal rubber, where they received information about clonal rubber and, if they had not yet adopted clonal rubber, where they usually received new information about rubber. From their answers (see Figure 5.5) it was found that most farmers (54%) obtained new information from other farmers in their neighbourhood in the village or their neighbourhood of their rubber garden. The other farmers got the information from researchers (20%), family (10%), farmers' group (5%), extension workers and self learning.

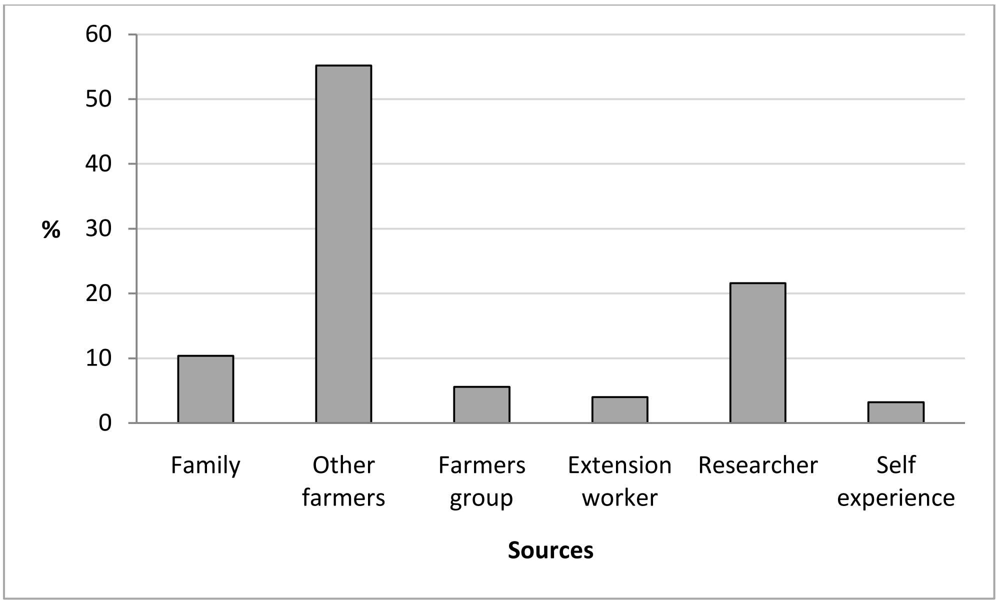


Figure 5.5 Sources of information for farmers in Jambi

There are several formats for information exchange among farmers such as during informal meetings for religious activities "*yasinan*"[1], conversation during the afternoon after finishing their work on the farm, while waiting to pray together or chatting in the coffee shop. These activities have an important role in the village in spreading information about introducing a new technology and information about activities in agriculture, such as schedules for planting, weeding or arrangements for the collective actions of *pelerin* or *gotong royong* (see chapter 4). Extension workers usually use *Yasinan* as a means to inform farmers regarding programmes or technical matters on agricultural activities.

[1] *Yasinan*; is reading one chapter of the Quran, the holy book for Muslims, together in a group at a mosque or at someone's house, mostly every Thursday night or another day that they have agreed to. This could be a specified group of men, women or youth only and is held at different times and includes prayer.

5.2.3 Categorisation of Respondents

Farmers moved through various stages as they moved towards adoption of clonal rubber, sometimes waiting some time before moving to another stage, sometimes moving to previous stages as circumstances changed. The categories of respondents as adopters and non adopters can be summarised and highlighted as follows:

1. The respondents who have a piece of land as the basic requirement to develop new rubber plantation, have potential to adopt clonal rubber. In the first field trip, all the respondents have a parcel of land that it is possible to use for clonal rubber. However in the second field trip there were two respondents who have no land and have a job as tapper for other farmers.
2. Some of the respondents believe in the higher production potential of clonal rubber compared to local rubber, including faster growth and time to get latex yield. Farmers in this category have more opportunity to adopt clonal rubber as they have basic motivation to adopt clonal rubber and positive expectation to get more yield. Others required more convincing and became interested after seeing demonstration plots (see 5 below).
3. Some of the respondents adopted clonal rubber as they have got incentives from the project. These respondents joined the ICRAF project and have got clonal seedlings and assistance from planting and managing.
4. Respondents who were interested in adopting however they have concerns about financial arrangements and limited access to capital, labour costs for land clearing, fencing, weeding, fertilising, pesticides and have no incentives. People in this category have less possibility for adopting clonal rubber without incentives.
5. Respondents who have seen clonal rubber from different sources such as demonstration plots, neighbour farmers or private or government rubber estates and they are interested as they have seen the faster growth or better yield of clonal rubber
6. Respondents who have seen unsuccessful demonstration plots of clonal rubber and believe there are potential weaknesses in clonal rubber such as low resistance to pests and diseases, inability to adapt to an intensive tapping system, the susceptibility of trees to falling down and those clonal trees

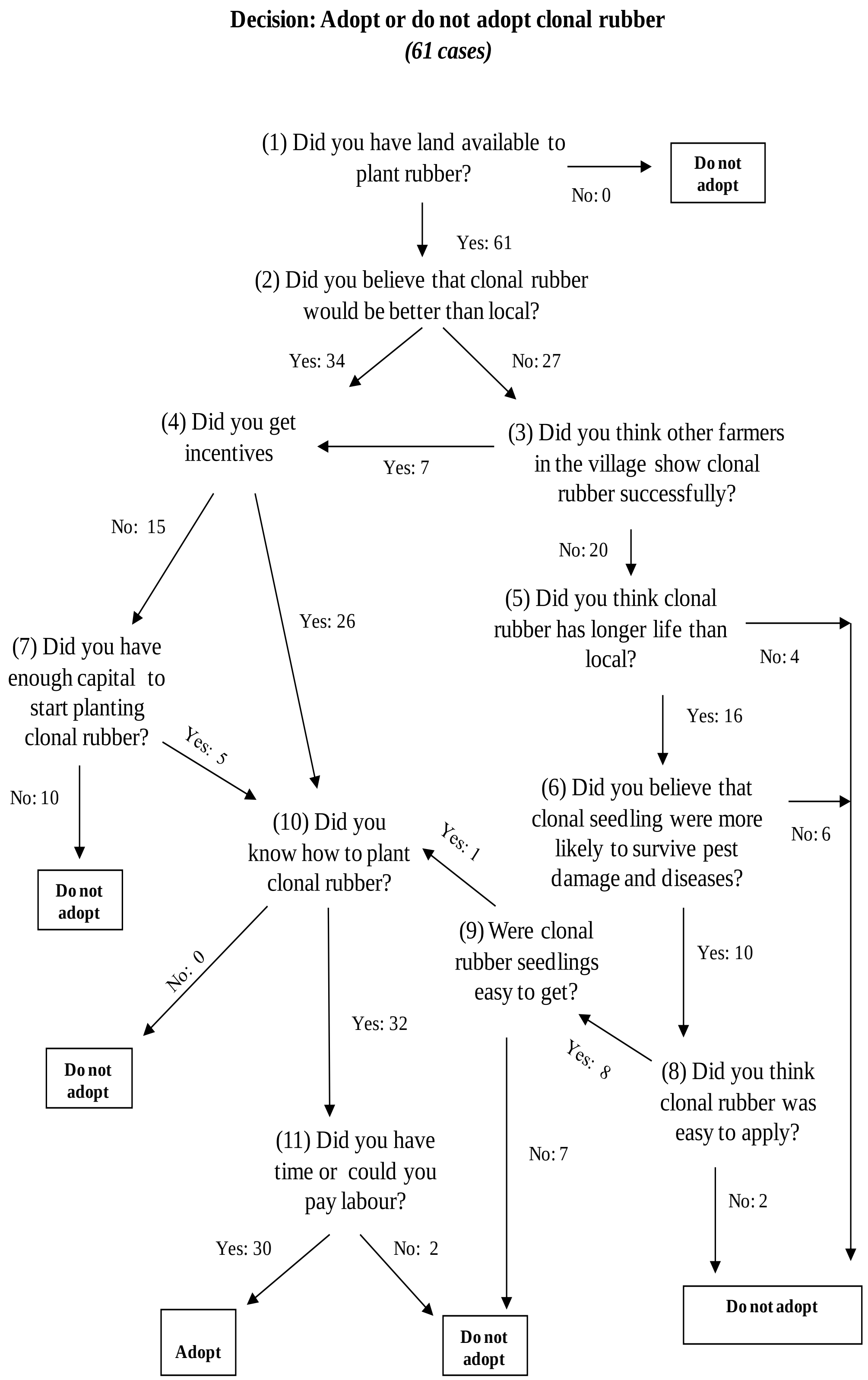
cannot grow together with other trees. Respondents who have had a bad experience with clonal rubber such as their rubber trees being attacked by fungi or falling over in strong winds, or finding that the second round of tapping does not produce latex, or the production has decreased, want to stop using new clonal rubber.

7. Respondents have concerns about technical knowledge, including the level of difficulty in managing clonal rubber, the workload, the time available to work on the farm, the availability of technical assistance, knowledge and skills in grafting, planting, fertilising, and maintaining clonal rubber, protecting clonal rubber from pests and disease, and sources of information. Respondents who only partially adopted clonal rubber and did not carry out all the protocols completely found it too hard to complete as they did not have adequate capital and labour.

5.3 The Decision Tree Model for Jambi

5.3.1 The Decision to Adopt or Not Adopt

In the first field research all respondents were interviewed using an open ended ethnographic interview to elicit their decision criteria. The results were formatted in a tree format containing decision criteria that lead the farmers to adopt clonal rubber and constraints that lead to rejection. These decision criteria were used by farmers to examine costs, risks, benefits and other factors of choices in deciding to plant or not to plant clonal rubber on their land. The decision tree model of Jambi location can be seen in Figure 5.6.



Note: The number shows the total farmers who said yes or no for each criterion, the number in the bracket to shows the criterion but not in order

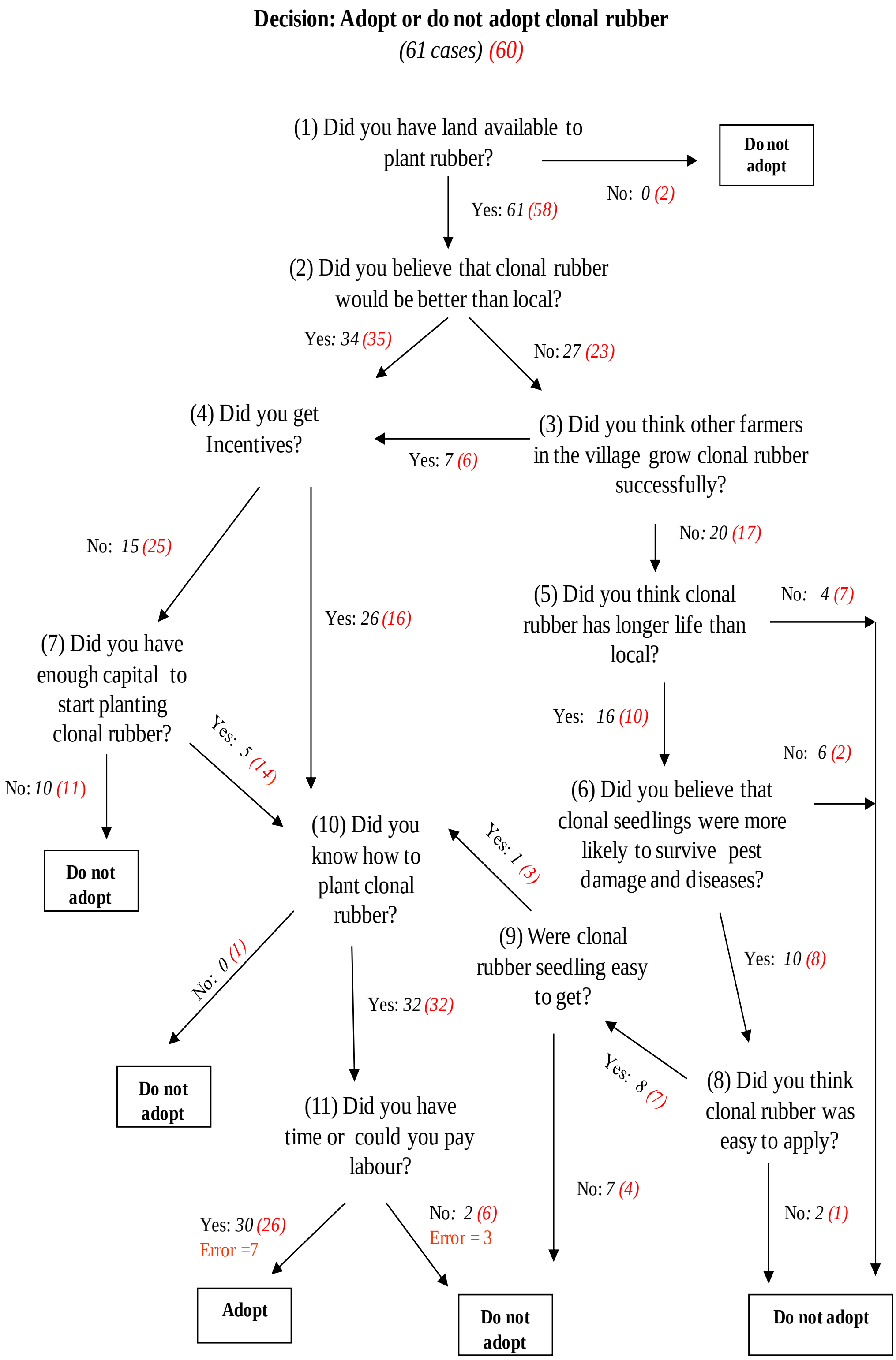
Figure 5.6 The decision tree model of adopting or not adopting clonal rubber by smallholder farmers in Jambi

The decision tree model highlights some criteria and constraints in Jambi in the decision making process for the adoption and rejection of clonal rubber and those identified can be used in other villages. Eleven decision criteria and constraints were identified from this decision tree. These are:

1) *Did you have land available to plant rubber?*
2) *Did you believe that clonal rubber would be better than local?*
3) *Did you get incentives?*
4) *Did you think other farmers in the village grow clonal rubber successfully?*
5) *Did you think clonal rubber was likely to have a longer life than local?*
6) *Did you have enough capital to start planting clonal rubber?*
7) *Did you believe that clonal seedlings were more likely to survive pest damage and diseases?*
8) *Did you think clonal rubber is easy to apply?*
9) *Were clonal rubber seedlings easy to get?*
10) *Did you know how to plant clonal rubber?*
11) *Did you have time or could you pay labour?*

5.3.2 The Test of the Decision Tree Model in Jambi

After the ethnographic decision tree of Jambi had been built based on the result of interviews in the first field research, then the model was tested with another group of farmers in different villages to measure its accuracy and predictability with other groups of farmers. The result of the testing of the decision tree models in two locations in Bungo districts, Jambi is shown in the figure 5.7



Notes : The number with red colour shows the total farmers who said yes or no for each criterion in the test 60 cases, 10 error, Predictability: 83%

Figure 5.7 The tested-decision tree model of adopting or not adopting clonal rubber by smallholder farmers in Jambi

As the rule of thumb for a good decision tree model it should predict around 80-90 percent of individual choices from various applications (Fairweather, 1992; Gladwin, 1989a; Gladwin, 1989b; Jangu, 1997; Murray-Prior, 1998), this study was in the range of a good decision tree model. The decision tree model developed from the first interviews was able to predict the responses of 50 farmers out of 60 farmers, or it made 10 errors. In this case the success rate is 83%.

$$\text{Success rate} = \frac{\text{total number of successes}}{\text{Total number of cases}} = \frac{(60\text{-}10) \times 100\%}{60} = 83\%$$

A good decision tree can predict between 80-90% of accuracy (Gladwin, 1989a), but in this case the success rate is 82%. An error in the testing of the decision tree happens if (1) the respondents are predicted to adopt clonal rubber as they passed all criteria and constraints, but in the end they do not, or (2) they did not pass the constraints but did adopt clonal rubber. There were two types of error that revealed to criterion no 11; seven farmers who said no they had no time but did adopt of clonal rubber. Meanwhile three farmers who said they had time or could pay labour did not adopt clonal rubber.

5.3.3 How Rubber Farmers Made Decision

How rubber the farmers come up to the decision of planting clonal rubber or not is explained below. This explanation is organised around criterion as numbered in the decision tree.

1. From the decision tree model, when clonal rubber was introduced, the first criterion was the availability of land for planting clonal rubber. Before deciding to plant clonal rubber, the farmers had to decide whether they have land available or not (criterion 1). At the time when clonal rubber was introduced most of respondents were rubber farmers and originally from these villages and all had access to land. The land area varied from 0.5 ha to more than 10 ha and the average land area owned by respondents was 4-5 ha. Land was in the form of old and unproductive jungle rubber, secondary forest or grassland.

2. The second question asked whether they were aware of and believed that clonal rubber had the potential to increase their rubber yield compared to local rubber (Criterion 2). Thirty four farmers believed that clonal rubber would be better than local, while twenty seven farmers, mostly not participating in the RAS project, did not yet believe in the potential of clonal rubber for various reasons. These farmers seemed to be selective in absorbing clonal rubber information or they had poor or incomplete information about clonal rubber. When the RAS project was introduced, some farmers already knew about clonal rubber. Thirty four farmers were encouraged to plant clonal rubber by the financial and technical incentives offered by the project (criterion 4). Meanwhile those who were not convinced in the beginning observed other farmers who have been introduced to clonal rubber earlier (criterion no 3) and the results were seven respondents were then convinced by other farmers and faced the next criterion of incentives (criterion no 4).But only twenty six farmers received incentives of free clonal seedlings and fertilisers as they can fulfil the request of ICRAF for establishment of demonstration plots. The other 15 farmers received no incentives and then asked themselves if they had enough capital (criterion 7). Ten respondents did not pass this criterion as they had no incentives and had no capital to start clonal rubber. These respondents ended with decision “do not adopt”.

3. The other five respondents said they had sufficient capital or access to capital to start clonal rubber and continued to criterion (10). This group consisted of farmers with adequate capital and farmers with off farm job such as teachers.

4. Thirty two farmers who have their own capital or incentives continue to the process the next criterion (10) and consider if they have technical knowledge of planting and managing clonal rubber.

5. The right side of decision tree started from criterion (3). Of twenty respondents who were not convinced by other farmers and did not think that clonal rubber was better than local or have not seen yet other clonal rubber, sixteen continued to criterion (5) and asked whether clonal rubber will last

longer in production and age. At this criterion, four farmers decided to stop the process and made a final decision not to adopt clonal rubber as they thought local rubber would have a longer life/age than clonal rubber. Each of these farmers still hoped that they could deliver their rubber garden to their son and grandson. As they had received rubber from their father and grandfather, they believed that they could deliver this jungle rubber to their children. They did not need to spend more time and money, just continue to tap.

6. Sixteen respondents who said agree or they thought the age of clonal rubber was longer or the same as the age of local rubber if they maintained it carefully then asked whether clonal rubber was more likely to survive to pest and diseases. Six farmers did not believe that clonal rubber will be more resistant to pests, especially wild pigs and monkey and they made the decision to continue planting local rubber. The farmers believed this problem is compounded if the tree's roots are attacked by white root fungus. Some of the farmers also blamed the spacing between rubber trees as the trees cannot support each other. They decided to not adopt clonal rubber.

7. Meanwhile 10 farmers continue to next criterion (8) whether clonal rubber was easy to plant and manage compared to local. Two of the respondents did not adopt clonal rubber because they thought that clonal rubber was difficult to apply and as not as simple as local rubber. Meanwhile eight farmers continue to criterion (9) and investigated whether clonal rubber seedlings were easy or difficult to get. Seven farmers did not pass this criterion as they faced difficulties getting affordable and pure clonal rubber seedlings close to their village. Local rubber and a variety of other types of rubber seedlings were easier to get rather than clonal rubber. These seven farmers decided to not adopt clonal rubber. Only one farmer continued to criterion (10).

8. In the criterion (10) the uncertain farmer joined those who passed criterion (4) and were asked if they had the technical knowledge of how to plant clonal rubber. Thirty two farmers passed this criterion and continued to criterion (11) whether they have time or could pay labour for planting and managing

clonal rubber. The result was thirty farmers decided to adopt clonal rubber and two farmers did not pass this criteria. From the 61 cases or respondents, 30 farmers decided to adopt clonal rubber and more than half (31 farmers) did not adopt clonal rubber.

5.4 Decision Criteria

The decision criteria from the decision tree model are analysed below and combined with evidence from the interviews and field observation.

1. Did you have land available to plant rubber?

First the respondents were asked whether or not they have land available to develop clonal rubber. Without land or if only a small area of land is available it is difficult for farmers to develop a clonal rubber plantation. People with limited land may have difficulties establishing a new rubber garden as they need an alternative source of income for their daily life.

2. Did you believe that clonal rubber would be better than local?

In the second criterion the farmers were asked whether they believed that clonal rubber would be better than local rubber (in their jungle rubber). Farmers decided to use the new clonal because they believed new clonal rubber might increase their latex. Most of the farmers had a high expectation that the yield of clonal rubber was going to be far higher than local rubber. Their belief came from their knowledge and experience as some of them have experience as a labourer in a clonal rubber estate in Malaysia or in a government clonal rubber estate.

While some farmers believed that clonal rubber will be better than local rubber, other farmers do not agree. Some because they have used local rubber for a long time and feel satisfied with it. Other farmers acknowledged the results from clonal rubber are good but they do not believe clonal rubber is superior in other characteristics such as tolerance to pest and diseases.

Most farmers with clonal rubber trees are euphoric when they get good yields from clonal rubber. With increased rubber yields and also a better price for rubber, they tap every day to maximise the result as they would with their local rubber. The main incentive for getting more results and more money was to buy modern products such as motorcycles and electronic equipment. Since the latex production and price has increased more farmers have bought motorcycles and pay these off using a credit system. Most of the farmers have no other income source and depend fully on the yield of their clonal rubber trees. Because they have to pay credit, some farmers maximise the tapping system to get more money. They did not follow the protocol that mentioned clonal rubber is not resistant to a very intensive tapping system.

The adopter farmers believe that the yield of clonal rubber was good and they were motivated to adopt clonal rubber because they want to get a better yield than they do from local rubber. Several factors may influence them to believe or not believe this. For example, they have seen firsthand that new clonal rubber produces a better yield than local rubber, or they have received information from other farmers or people whom they trust.

> The first time I saw people from ICRAF introducing clonal rubber to farmers here was in a demonstration plot. I saw the seedlings were good and grew faster than local rubber. There was no result yet, but I was interested in the fast growth. I asked them about those clonal seedlings and I heard that the yield is better than local. My little brother who had seen clonal rubber in other provinces said he would support me in planting clonal rubber. So I tried to plant clonal rubber when I replanted my old rubber plantation. The seedlings' price was more expensive when compared to local rubber, but I want to get good results. (Adopter, Sepungur).

However, the non adopter farmers did not believe clonal would be better than local rubber. There were some possible reasons behind this. The first reason was that the information on clonal rubber was not reliable. For example the farmers have heard about the weaknesses of clonal rubber from their friends. Some of this information comes from traders of seedlings who promoted their own seedlings and is unsubstantiated.

In addition, some of the farmers in the study sites have experience in joining the project such as government projects. However the seedlings they received from the project were poor quality seedlings that resulted in low latex production. They were disappointed after they had spent time, money and effort to raise the rubber trees.

3. Did you think other farmers in the village grow clonal rubber successfully?

Some of the farmers in Jambi believe that the growth and yield of clonal rubber was below their expectations. This was because they had experience in planting clonal rubber from the government project and the quality and purity of seedlings were not good. Or they have seen unsuccessful demonstration plots and they believe clonal has the same or an even lower yield than local rubber. Demonstration plots of the RAS project were based on farm trials which are established on the farmers' land. The farmers have responsibilities to maintain rubber plantations by following the protocols set by the researcher. The project has the responsibility for providing clonal rubber seedlings, fertilisers, pesticides, as well as training and monitoring. During implementation the participation of the farmers in demonstration plots could have failed, especially if farmers have low motivation or received inadequate assistance.

Demonstration plots have become important for farmers as farmers were convinced that clonal rubber was better after they have seen the results and they become interested in adopting clonal rubber. However unsuccessful demonstration plots caused by factors such as technical error (pest and diseases), natural hazards (landslides, wind), and non technical errors (abandoned procedures), have a negative impression on farmers. Some farmers do not look into the causes deeply and comprehensively as they were only interested in the results. They do not investigate the causes of failure, which sometimes happen not because it was clonal rubber, but because some protocols for clonal rubber were not followed by the farmers.

4. Did you get incentives?

The third criterion for farmers in Jambi to choose clonal rubber was because they were interested in getting financial and technical incentives from the project. Incentives such as free clonal seedlings, free fertilisers and pesticides were an important factor for farmers to adopt clonal rubber, especially farmers who have no capital or access to the planting materials of the new technology.

Farmers may be interested in trying or adopting because they will get incentives from the project. Mostly, farmers who did not join the project and did not get an incentive have difficulties adopting clonal rubber. They want to adopt but cannot afford the cost of good quality improved clonal rubber planting materials, fertiliser or technical knowledge via training.

> I heard that ICRAF are looking for demonstration plots and will offer free clonal seedlings and fertilisers, so I was interested to plant as also I heard the results are good (Adopter, Sepunggur).

> I have old rubber to replant. My brother said there is someone who will give us free good seedlings and fertilizer and so on, but we have to do the work. So I met them (ICRAF) and told them that I was interested, that I have spare land close to the main road that would be good for a demonstration plot. I was interested because it's free, and they said they were good seedlings and I do not need to pay for them (Adopter, Sepunggur).

5. ***Did you believe that clonal seedlings were likely to have longer life than local and***

6. ***Did you believe that clonal seedlings were more likely to survive pest damage and diseases?***

There is a belief that local seedlings were stronger and live longer as were more resistant to pests and intensive tapping than clonal rubber. Some of the farmers believe that the life of clonal rubber was shorter than local rubber as people harvest their parents' rubber plantations for years.

The context of age could differ between farmers and researchers. The longer age in farmers' perceptions comes from: (1) Rubber trees were mostly tapped at the age of 10-15 years compared to clonal at 5-7 years of age, and so they possibly live longer, (2) Living longer in the context of rubber trees as plantations but not as individual rubber trees. Farmers plant more than 500 trees in one hectare without uniform distances between trees. As there was limited labour farmers tap only part of the rubber trees and tap the other rubber trees later, so they might continue to tap different trees in the same area longer (3), Farmers allow the natural succession of rubber trees. Each dead rubber plant was replaced with a seedling that grows naturally around the old rubber tree or they plant local seedlings between mature rubber trees. This is called "*sisipan*".

One respondent said:

> Local seedlings are stronger than clonal. The productive life of a clonal tree is limited to only 25 years but local may last longer than that; it can be tapped by our sons and grandsons. You can see in my neighbour's clonal rubber plantation most of them have fallen down after reaching probably 10 years of age (Non adopter, Sepunggur)

> I do not like clonal rubber as I have seen how easily the trees fall down as their roots are not strong enough. That is the disadvantage of clonal rubber (Non adopter, Rantau Pandan).

Farmers believe that clonal was easily attacked by pests and diseases. They believe the clonal seedlings were more vulnerable to vertebrate pest damage such as from wild pigs (*Sus scrofa*) and monkeys (*Presbytis melalophos nobilis*) than local rubber. In the study area, especially Rantau Pandan village, pests were a major constraint. Traditionally farmers plant local rubber seedlings when the seedling height was greater than 1 metre. This was an advantage because at this height the rubber tree was less likely to be destroyed by wild pigs. They also believe that weeding regularly may increase the exposure of seedlings to wild pigs. One of the respondents said

> I have been frustrated because young rubber that I had just planted was damaged by wild pigs and monkeys. So, young clonal rubber trees must be protected by my staying all day in the garden (Adopter, Rantau Pandan).

Wild pigs usually damage the roots and young stems of young rubber trees. Farmers mostly said that wild pigs were the most destructive pests that need to be kept away from the plants at this time, followed by other animals such as monkeys and cows. Almost all farmers mentioned pigs and monkeys as pests of rubber trees, especially clonal rubber.

> I do not want to adopt clonal rubber as I have no time to guard a clonal garden that is easily destroyed by wild pigs as the seedlings are not high enough and the plants are destroyed even though the area is already fenced. And if I do not monitor frequently the plants will be destroyed by wild pigs and/or monkeys. I think local rubber is more resistant to pests and diseases and more resistant to wind, as local rubber trees rarely fall down, while clonal easily falls down (Non Adopter, Rantau Pandan).

Rantau Pandan village was surrounded by forest which was the habitat for wild animals. From the stories of the older people it was found that in the past there were not many pigs and monkeys that came to their rubber plantations or paddy fields. These animals lived in their own habitat with sufficient food available in the forest. But since the area of forest has decreased because of logging activities for timber or conversion of forest to agricultural land, the forest's function as a habitat and food provider has diminished. This situation pushes the wild pigs into human areas such as rubber agroforestry to find food and shelter. The pigs like to crush the roots of rubber seedlings, to dig the soil surrounding the seedlings to find bugs or to scratch their bodies on the seedlings. As a result the seedlings become damaged or broken.

The population of pigs was difficult to reduce as some conditions of the area environmentally and culturally supported the existence of wild pig. The extinction of predators of wild pigs such as tiger and ability of female pigs to produce a large number of piglets has probably led to a rapid increase in pig population. In addition probably because most of the farmers were Muslim and in Islam they are not allowed ("*haram*") to consume pork/pig or to hunt and take benefit from selling it, so pigs are not hunted.

Another factor in their decision was that farmers believe that clonal rubber was less resistant to diseases and some of the fungi, such as white root fungi they believe may attack and destroy their rubber. Non adopters in Sepunggur have seen clonal rubber demonstration plots were damaged by white root fungi. This disease spreads very easily to other trees and was difficult to prevent for two main reasons: (1) Most of the farmers did not do prevention in the beginning of establishment rubber garden (2) The farmers did not recognise the early symptoms and only realised after several trees have been attacked (3) The farmers have no fungicides because they could not afford to buy pesticides or they were not available in the market.

The clonal rubber also was damaged because of over exploitation. Ideally, based on the protocol clonal rubber trees should be tapped a maximum of 3-4 times a week and also tapping was prohibited after or during rain. However, to maximise the yield most of the farmers do tapping every day similar to the tapping system for local rubber. As a result a lot of rubber trees died young. The main reason that the farmers maximise results was to pay off credit on new items they have bought such as a new motorcycle. With the promise of increased latex production from clonal rubber trees and the increase in the price for latex some farmers bought motorcycles and paid for them on credit. Mostly they have no other income sources except the yield from their clonal rubber trees. For this reason the protocol for tapping latex mostly did not work.

7. ***Did you have enough capital to start planting clonal rubber?***

In general, although some of the farmers know that clonal rubber has a better yield, the cost of establishing clonal rubber was higher than they can afford; especially if the farmers were thinking that clonal rubber should be monoculture and requires an intensive system. Some non adopter respondents said:

> Clonal rubber needs more capital, I have to do fertilising and weeding regularly, I have no money. But if the government gives us clonal seedlings, fertiliser and cash for weeding it will be good for us as we have no capital, not like rich farmers (Non adopter Rantau Pandan)
>
> I am not interested in clonal rubber seedlings yet, mainly because of their high cost and they must be fenced. I have heard that without fencing they will not grow better. And the seedlings are difficult to bring to the field. I can transport 300 seedlings to the field in one trip, but it is impossible to do this with clonal seedlings as they need a polybag (Non adopter, Rantau Pandan).
>
> I gave up the idea of having clonal rubber. I cannot plant clonal rubber as I do not have the ability to guard the rubber garden. I have to put on pesticides and fence the garden. Clonal rubber is very demanding. I can't do maintenance like that even though I have heard that the results of clonal rubber are better than local (Non adopter, R Pandan).
>
> Only rich people with enough money can plant clonal rubber, as they have a regular and secure income every month for their daily life. They can ask their employees to help them or pay labour. We are poor people who have no capital and clonal rubber needs more money for fertilizing, weeding and fencing [than local]. Our income is totally dependent on rubber. If we have to establish new clonal rubber, we have no money for everyday life. Who will earn an income for daily life when we are establishing clonal rubber until it achieves results? (Non adopter, Rantau Pandan).
>
> Capital is very important for me. Capital is number one that we need to establish a rubber garden. In the past we did not need much capital

> to establish a garden and we could handle it ourselves and we did not need to owe anything to other farmers. But as for clonal rubber, we were surprised that we need more capital and have no resources [to get it] (Non adopter, Sepunggur).

Capital becomes an important constraint for farmers in the adoption of clonal rubber. Farmers think the cost of establishing clonal rubber was far higher than local rubber. They have to buy clonal rubber rather than get it for free from existing old rubber, and also pay for fencing to protect the plants from pests, as well as fertiliser and herbicides.

1. The Rubber Agroforestry System is an innovation for the rubber farmers and was quite different from their traditional system. For example, they have to buy rubber seedlings rather than get them for free from the old jungle rubber. The clonal seedlings were more than double the price of local seedlings. In the jungle rubber system planting material can be obtained freely, or at low cost if bought in a traditional market. The price of clonal seedlings from private nurseries was more than twice the price of local seedlings and this did not include the cost to transport the seedlings. In addition the seedlings sold by traders were of poor quality and there was no guarantee of the purity of clonal seedlings. The farmers do not want to take a risk spending money on low quality clonal seedlings.

2. The farmers have to establish a fence to protect the young trees from pests especially pigs and other animals such as domesticated cows, sheep and buffalo that are left to forage freely. Protection was important because of the large investment in clonal rubber seedlings.

3. Clonal seedlings were grown in a polybag before planting out in the field whereas local seedlings can be planted directly from the stump. If the location of the farmer's rubber garden is far from his house transportation will be a problem. Farmers bring more than 100 local seedling stumps to the field in one trip. In contrast they can only transport around 20 clonal seedlings in one trip on a motorcycle.

4. Fertilising: the clonal seedlings need fertiliser to grow and yield well. However during planting time sometimes fertiliser was not available in the market or, if it was available the price was very expensive. As a result fertiliser may not be applied in quantities or at the frequency required to achieve the desired growth and yield.

5. Pesticides: Some clonal seedlings were not resistant to pests and diseases and need to be protected or, where infestation has occurred, remedies need to be applied. Some fungi need to be eliminated as soon as possible to prevent damage in the infected tree and to prevent it spreading to surrounding trees. Pesticides are sometimes expensive in the market.

6. Establishing a new rubber plantation will mean that the farmer will have to work on the new land and may have no other source of income for the family's daily life because the farmer has no time to tap latex from his old rubber plantation. One farmer asked for support and wages from the government for their daily living expenses while they opened a new rubber plantation using the new system.

8. Did you think clonal rubber was easy to apply?

Most of the smallholder farmers in Jambi have experience in local rubber and have been involved in the jungle rubber system. This traditional system was characterised by utilising unselected seedlings for planting materials, providing no fencing, no regular weeding, no fertiliser and mostly low maintenance until the rubber was ready to tap. Planting and managing intensive clonal rubber requires more procedures and work to follow. The farmers have heard that clonal rubber will grow faster, can be tapped earlier and the yield was better than local rubber, but it requires a lot more work and effort. Once they have replaced with clonal rubber farmers have to follow an improved cultivation system such as applying planting distances, regular weeding, fertilising, and management of pests and diseases and applying a different tapping system to get the best results from clonal rubber. Clonal rubber requires more intensive management such as regular weeding and fertilising, therefore it needs continual inputs of time, labour, money and also skills and knowledge. Some farmers believe it was too complicated to start clonal rubber and they prefer to plant local rubber.

> I don't remember what year I was offered clonal rubber to plant, but I do not want to, even though they will give me fertilizer and pesticides. I do not want to plant clonal rubber. I saw some people here planted clonal but I do not want to because of the high cost and demanding maintenance, which is not as simple as for local rubber. Local rubber is very easy to maintain and does not need to be fenced (Non adopter, Rantau Pandan).

> It is difficult to transport clonal rubber from home to the field. It produces more latex compared to local, but it is difficult to maintain, I have to do fertilizing and weeding and it must be checked regularly. We do not need to go and check local rubber regularly. Planting clonal rubber was hard to do and too complicated (Non adopter, Sepunggur)

9. Were clonal rubber seedlings easy to get?

Some farmers have a problem in getting good quality clonal seedlings, especially in Jambi. The nurseries that provide clonal rubber in the study site in Jambi, sometimes deliver seedlings whose quality and purity were questionable and the price was high. Some of the farmers bought and tried to plant those different seedlings on their land, in the hope that the yield would be better than the local. In addition, credit from the government was limited and free seedlings from the previous government project sometimes were of low quality.

> Guaranteed clonal rubber seedlings are difficult to find, especially if we do not know what they look like. Many traders say they sell clonal rubber seedlings but actually they sell different seedlings. So, it is difficult to find guaranteed clonal seedlings (Non adopter, Rantau Pandan).

Pure and guaranteed clonal planting material is important and pure clonal seedlings are difficult to obtain at the village and sub district level. There were different types of seedlings available in the village such as "*bibit Malaysia* (Malaysian seedling), "*bibit kawin tiga*, *bibit Sembawa*" that are mostly sold by traders but there was no guarantee of the purity of the seedlings and none of them are recommended by the Centre of Rubber Research.

10. Did you have the technical knowledge to plant clonal rubber?

Technical assistance was an important factor since clonal was new to farmers. Farmers did not want to adopt as they do not know how to establish or how to manage clonal rubber. Some farmers found difficulty in the technical aspects of clonal rubber management such as knowledge and skills in grafting, planting, fertilising, protecting rubber plants from pests and disease and the tapping system. One of the causes of the lack of success in introducing clonal rubber was because farmers do not know how to apply a particular protocol to their rubber plantation, especially in preventing and curing infection caused by diseases such as fungi. Farmers do not want to adopt something for which they did not have the skills. Lack of extension may be one reason that farmers have insufficient information and lack of technical knowledge about clonal rubber.

11. Did you have time or could you pay labour?

Time and labour availability were important in the decision to adopt clonal rubber for farmers in Jambi. The management of a clonal rubber plantation was different and farmers believe additional time was required for the management of clonal rubber. The farmers may also believe there was a time saving in tapping clonal rubber as clonal rubber has a standard distance between trees. However in the management of other activities clonal rubber was more time demanding than local rubber. Some farmers usually also had wetland paddy and other agricultural land to manage. Also, some farmers have off farm jobs as a teacher, trader, civil service, and army. Some respondents with an off farm job find it difficult to find time to manage their clonal rubber. For these reasons availability of time became an important criterion.

Traditionally the farmers cleared forest land, planted local rubber and left it until it was time to start tapping the trees. The clonal rubber system was more complicated. The farmers believe that clonal rubber plantations need more labour especially for weeding, fertilising and guarding in the early stages of establishing the rubber plantation when it was vulnerable to pest attacks. Most of the work in the rubber plantation was carried out by the farmer, his wife and his family members. Only farmers who have enough capital can pay labour to undertake the work on their rubber plantation.

5.5 Summary

The farmers in Jambi were motivated and interested to adopt clonal rubber by availability of land, their belief that clonal rubber would provide better yields and project incentives to adopt clonal rubber. Those farmers who had land, capital or they received incentives, obtained the necessary knowledge and they had time and labour to cultivate and manage clonal rubber. However some farmers faced constraints on access to capital to start clonal rubber, access to clonal seedlings, technical knowledge, pest and disease and lack of labour. When they did not pass these criteria or constraints they did not adopt clonal rubber.

The result shows that testing of decision tree in 60 cases found 10 errors; therefore the accuracy of model is 83%. Based on Gladwin's criteria (1989a) the model was able to predict decision making behaviour to adopt or not adopt clonal rubber in Jambi with reasonable accuracy.

Chapter 6 The Decision Tree Model for West Kalimantan

6.1 Introduction

This chapter discusses the results for the location of West Kalimantan Province. The structure of this chapter is similar to Chapter 5. It presents the socioeconomic characteristics of respondents based on interviews, secondary data and field observations. Next, the results from the ethnographic interviews are summarised and presented in a decision tree format. The decision tree model represents the decision making steps and the decision criteria that the farmers use. The decision criteria and the results of the tested factors of the decision tree are discussed in detail in terms of factors involved in decision making by rubber farmers.

6.2 Characteristics of Respondents

6.2.1 Socioeconomic

The characteristics of respondents in the study sites are namely, age distribution, level of education, land ownership, experience in rubber, family size and gross annual income rate. These are presented in Figure 6.1.

The number of respondents totalled 108 rubber farmers in four villages in Sanggau District, West Kalimantan, namely Pana, Senunuk, Embaong and Kopar. The majority of the respondents in this research were aged between 31-59 years. Most of the respondents were married and only five were unmarried or widowed. All of the respondents were in the productive age (based on the categorisation of Central Bureau of Statistics of Indonesia (BPS) productive age is more than 15years old). The average size of family was 3-4 persons (55%), and the family working in the rubber garden was limited to the head of the household and his wife. Ninety percent of the families stayed in one house as a single family and ten percent in one house with their parents, or with their brothers or sisters.

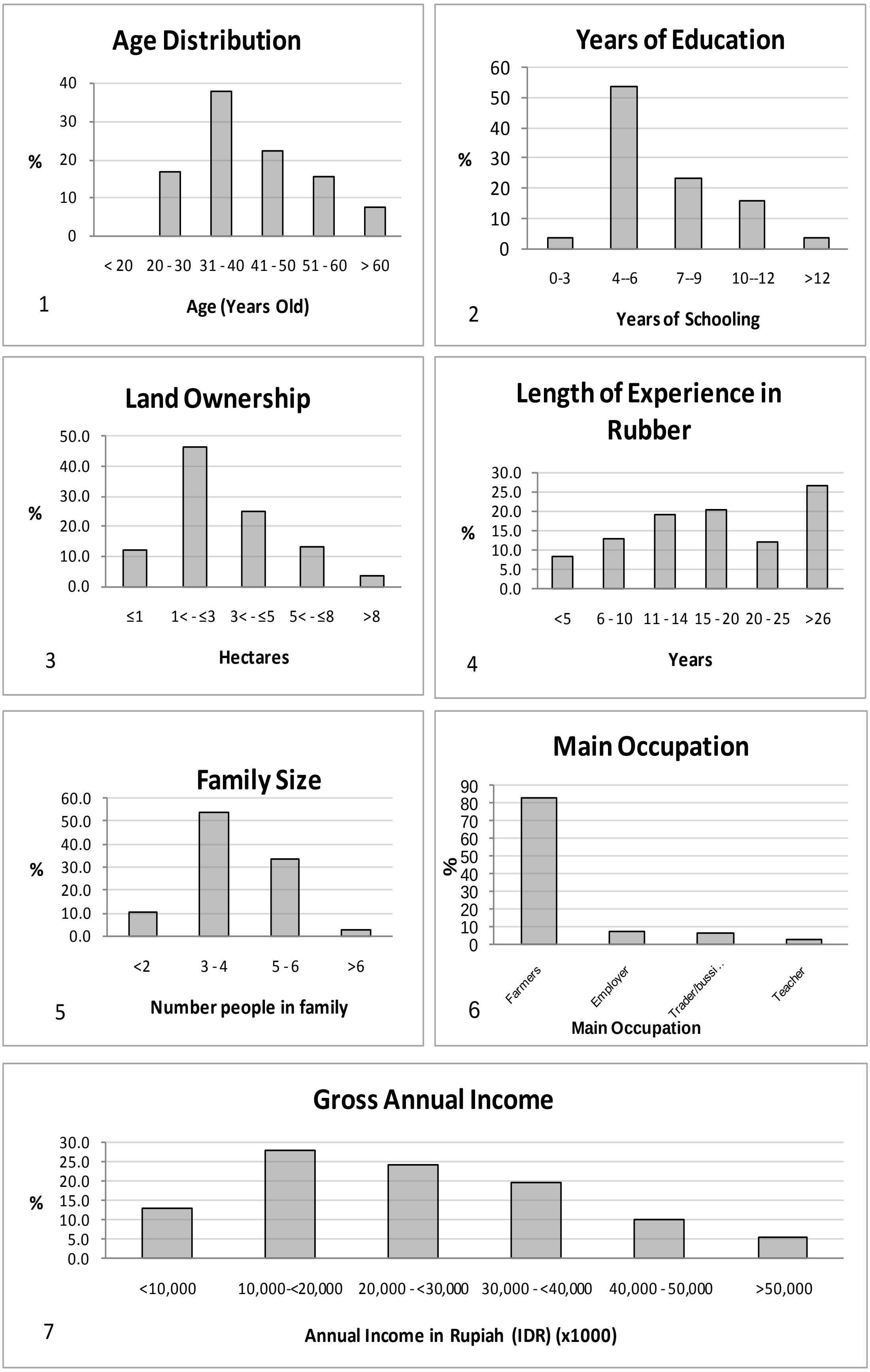


Figure 6.1 Socio economic characteristics of respondents

Fifty five percent of the respondents had 4-6 years of education (elementary) school, only twenty two percent of them finished intermediate school and fewer than ten percent had high school education. The respondents had more than 10 years experience in rubber gardens (75%), since they have been involved in rubber activities together with their parents since they were young.

Land size ownership was an indicator of rubber production and may influence the decision to adopt clonal rubber or not. A household's land holding in these areas of study was between 0.01 – 20 Ha. On average, the respondents held land of 1-3 ha (45%) and fewer than 10% had more than 8 ha of land. Most of the land was planted in rubber, the other in oil palm and other crops.

The highest percentage of annual gross income of respondents was IDR 10 million to 20 million or equal to USD1000-2000. The annual gross income was estimated from the average of their income from their rubber garden per month and other income if they had an off farm job. The main occupation of respondents was rubber farming (84%), the others were employed in the private companies such as oil plantation estates with monthly salaries for working six days a week. The other respondents were traders or had their own business such as being a middle trader for rubber (toke) and running small shops (6%). The smallest percentage of respondents consisted of teachers in the local school in the village (3%). Even though their main job was not as a rubber farmer, all respondents owned rubber gardens to manage and to use as a source of income.

6.2.2 Characteristics of Rubber Management

1. Objective

The main objective of the establishment of rubber in West Kalimantan was to achieve economic fulfilment, or as a main source of income of households. This can be shown from Figure 6.2. Most of the respondents were rubber farmers who have the objective of establishing a rubber garden as a main income source (75%). The other respondents (12%) mentioned it as additional income, as they have a main job such as a teacher, an employee on a private estate or a trader. The typical farmers who also had a second job (10%) said that rubber latex was for saving, as usually they put their money in the Credit Union (CU) that has become popular in West Kalimantan. Some respondents (4%) specifically mentioned that the rubber yield was mostly to help them afford education costs for their children. Some of the farmers have multiple objectives in planting clonal rubber that were mostly close to the economic objective. Some of them also mentioned that a better income from their rubber will help them buy a motorcycle for transportation and to renovate their house.

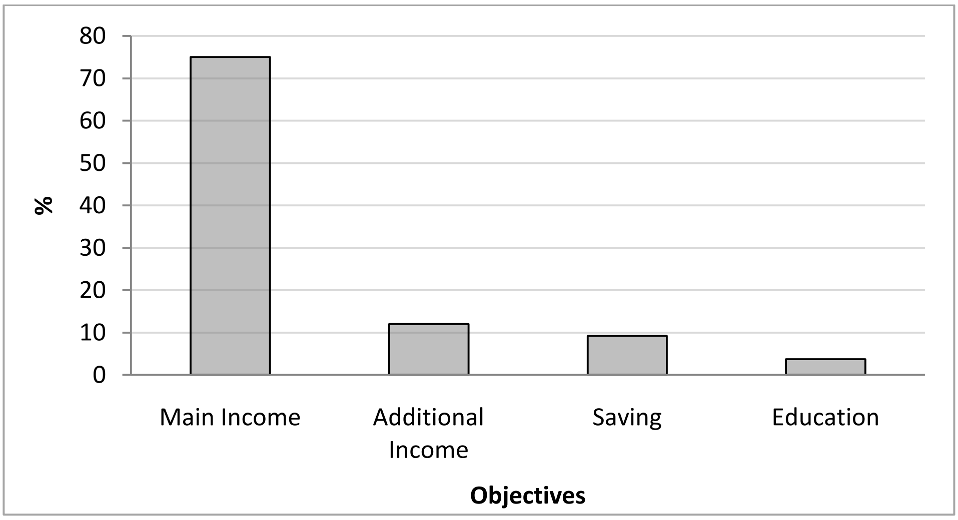


Figure 6.2 Farmers' objectives in rubber planting

As a main source of income to fulfil their daily household needs, the farmers responded to possibilities of increasing rubber yield. The introduction of clonal rubber also was regarded by farmers as an opportunity to increase their rubber yield.

2. *Labour system*

There are three types of labour that are applicable in the establishment and maintenance of rubber gardens in Sanggau West Kalimantan. From the interview it was found that in establishing and maintaining rubber the farmers use family labour, paid labour and collective labour. The type of labour is shown in figure 6.3.

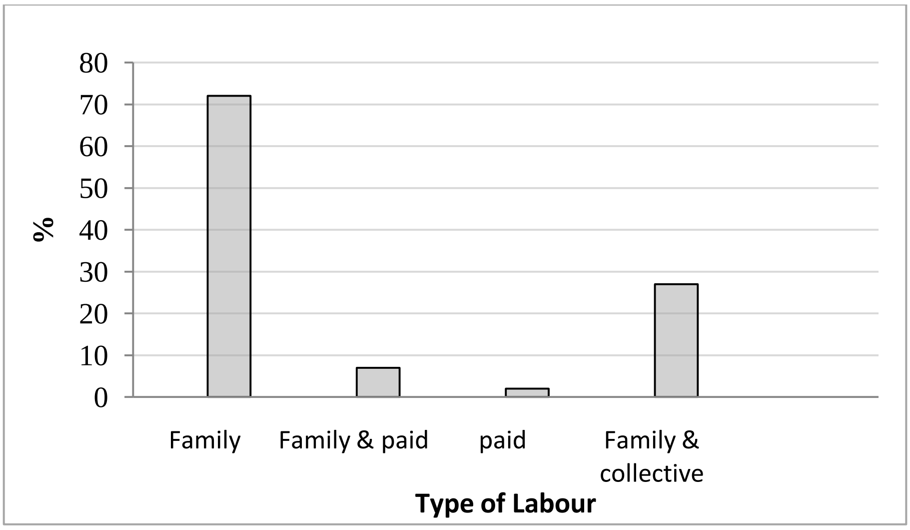


Figure 6.3 Type of labor in rubber garden in West Kalimantan

a. Family Labour

About seventy percent of the farmers use the family as the main source of labour for rubber garden jobs and 7% use a combination of family and paid labour. These family members can be husband, wife, children (daughters and sons), their parents, their daughters or sons in law or and they are categorised as being in the productive age (15 to 60 years old) or they are married. Most of the households in Sanggau have only 2-3 family members who work in the rubber garden (see figure 6.4).

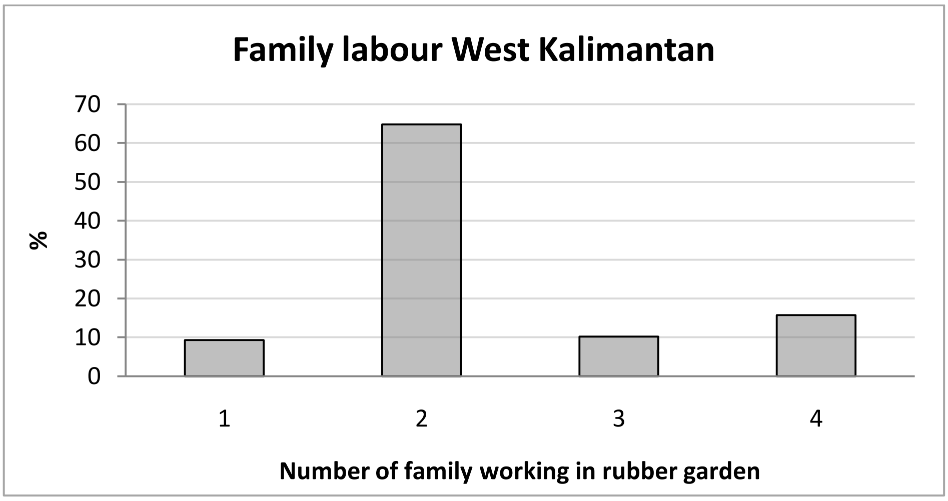


Figure 6.4 Number of family members working in rubber garden in West Kalimantan

b. Collective labour/community labour

Twenty eight percent of farmers in four villages in Sanggau combined family labour with collective labour to establish and manage their rubber garden. They used traditional collective labour such as *pengarih* (see Chapter 4 part 4.2.4) and also formal farmers' groups that were established together with field staff or extension workers.

c. Paid Labour

Respondents in Sanggau used paid labour (2%) and combined family and paid labour (7%). Paid labour was common in rubber gardens in Sanggau, West Kalimantan and was a substitute for family labour. There were two types of paid labour, permanent and seasonal paid labour. The main type in Sanggau was seasonal labour, as most of the farmers used paid labour in the particular season only, such as tapping in the season of harvesting paddy rice or palm oil. The wages for paid labour usually varied between IDR 25.000 to 50.000 (US$2.5-5) per day depending on location, type of job and seasons. Paid labour was also common for clearing old rubber and planting rubber. The availability of labour has an important role in the decision making process of the farmers in the adoption of clonal rubber.

3. Sources of information

In the process of decision making over the adoption of clonal rubber, the role of information was very important. Twenty eight percent of respondents in West Kalimantan said they gained information on clonal rubber from field researchers who had good contact with the farmers. The farmers heard about clonal rubber and learned techniques from field assistants and ICRAF researchers.

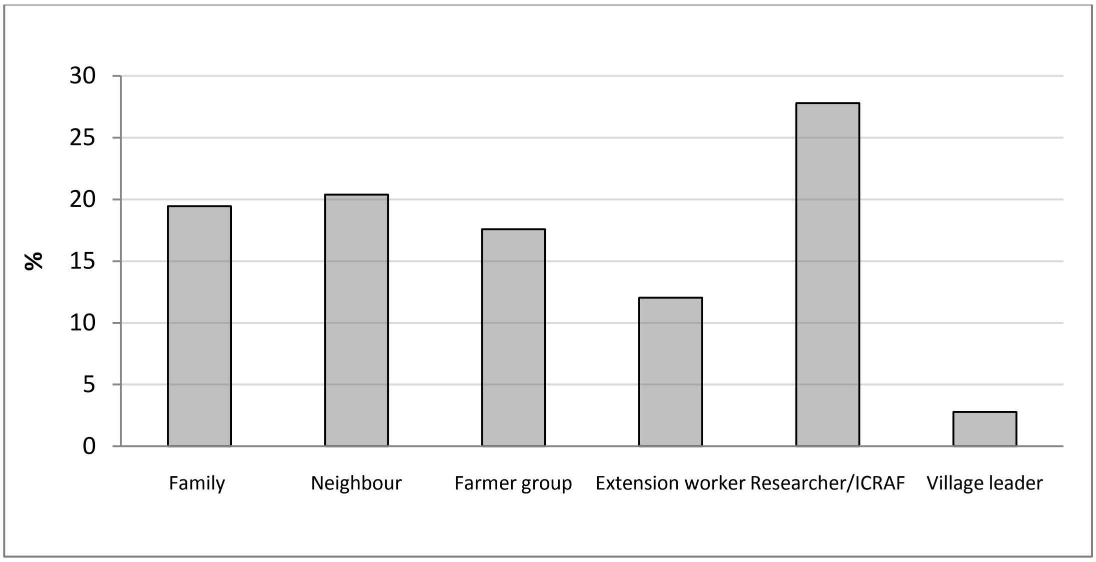


Figure 6.5 The sources of information on clonal rubber in West Kalimantan

Other farmers received information from their own neighbours (close in term of house or rubber garden location) who had information or who had applied clonal rubber on their land (21%). These respondents were more confident in adopting clonal rubber after observing and acquiring sufficient information about clonal rubber from friends or neighbours who had already planted clonal rubber. The active and innovative farmers had an important role in spreading information on clonal rubber as they had regular contact with field assistants. The farmer's family members including parents, uncles and other extended family members also have an important role in spreading information and become the third most important source of information (19%). In Pana village it was found that farmers were interested and planted clonal rubber after getting information and observing their relative's clonal rubber. The role of extension workers and village leaders as sources of information is less than the other sources as they rarely have contact with the farmers.

In Pana and other villages in West Kalimantan, farmers' group became an important source of information (18%). The farmers' groups have a multi-function as places for information about clonal rubber from a researcher in a formal meeting, or from other farmer group members. The farmers may exchange information about their experience in planting clonal rubber. The leaders of farmers' groups were usually progressive farmers who have contact with government officers, extension workers and researchers. Their role gives more information when farmer's group members made decisions.

6.2.3 Categorisation of Respondents

Based on the interviews and field observation, respondents in West Kalimantan can be categorised as:

1. Respondents as adopters who had full incentives. They received clonal seedlings, fertiliser, herbicides and pesticides. They also received training and technical assistance starting from the establishment of a rubber garden until they started to tap the latex.

2. Respondents who learned from previous adopters and had limited incentives (for these categories ICRAF only provided technical training and field trips to see the clonal garden demonstration plots). By having technical knowledge they started to develop their own clonal garden together with the members of their farmers' group and they proposed to get more free clonal seedlings and fertiliser from local government (Dishutbun). Based on their knowledge from the training they developed nurseries by themselves to produce clonal rubber seedlings using their own capital in their farmers' group. They fulfilled the need for seedlings for their members of the farmers' group or to sell to other farmers.

3. Respondents who chose rubber clonal gardens because they have seen the result from the previous success of rubber gardens especially the farmers surrounding the demonstration plot. They had their own capital to buy seedlings, fertilisers and herbicides. Most of them were farmers with other off farm jobs such as traders, teachers or employers in a private company.

4. Potential adopters have had training but they are waiting for incentives or a project from government. Most of them have problems with capital to start their clonal rubber. They have technical knowledge and were interested in planting clonal rubber but they were waiting for projects that have been promised to them. The farmers want to plant clonal rubber but have no incentives such as free seedlings and have no technical knowledge to produce clonal seedlings. They learned from other farmers who had relationships with them and then they started with small plots using their limited capital.

5. Non adopters who have a problem because they were not involved in any project. The location of their land was far from home so it cannot be managed using intensive management, as it was difficult to visit and to control. They choose to plant local rubber for saving land and to deliver a resource to their son and grandson in the future.

6. Non adopters who have no technical information, have no capital or incentives from any projects, and have no time, but they have land and were interested in planting clonal rubber. Some farmers think that clonal rubber needs more capital and work compared to local. To get more income, some of them choose to become employed on an oil palm plantation. In Senunuk, these categories mostly were younger farmers. This village has close access to the city and some private estates that have been developing oil palm plantations providing opportunities for jobs.

6.3 Decision Tree Model for West Kalimantan

6.3.1 Decision to Adopt or Not Adopt

The decision tree model shows the process of adoption of clonal rubber in two villages in Sanggau. The decision tree in Figure 6.6 shows the criteria in the process of making a decision to adopt or not adopt clonal rubber by rubber farmers in four villages in Sanggau District, West Kalimantan.

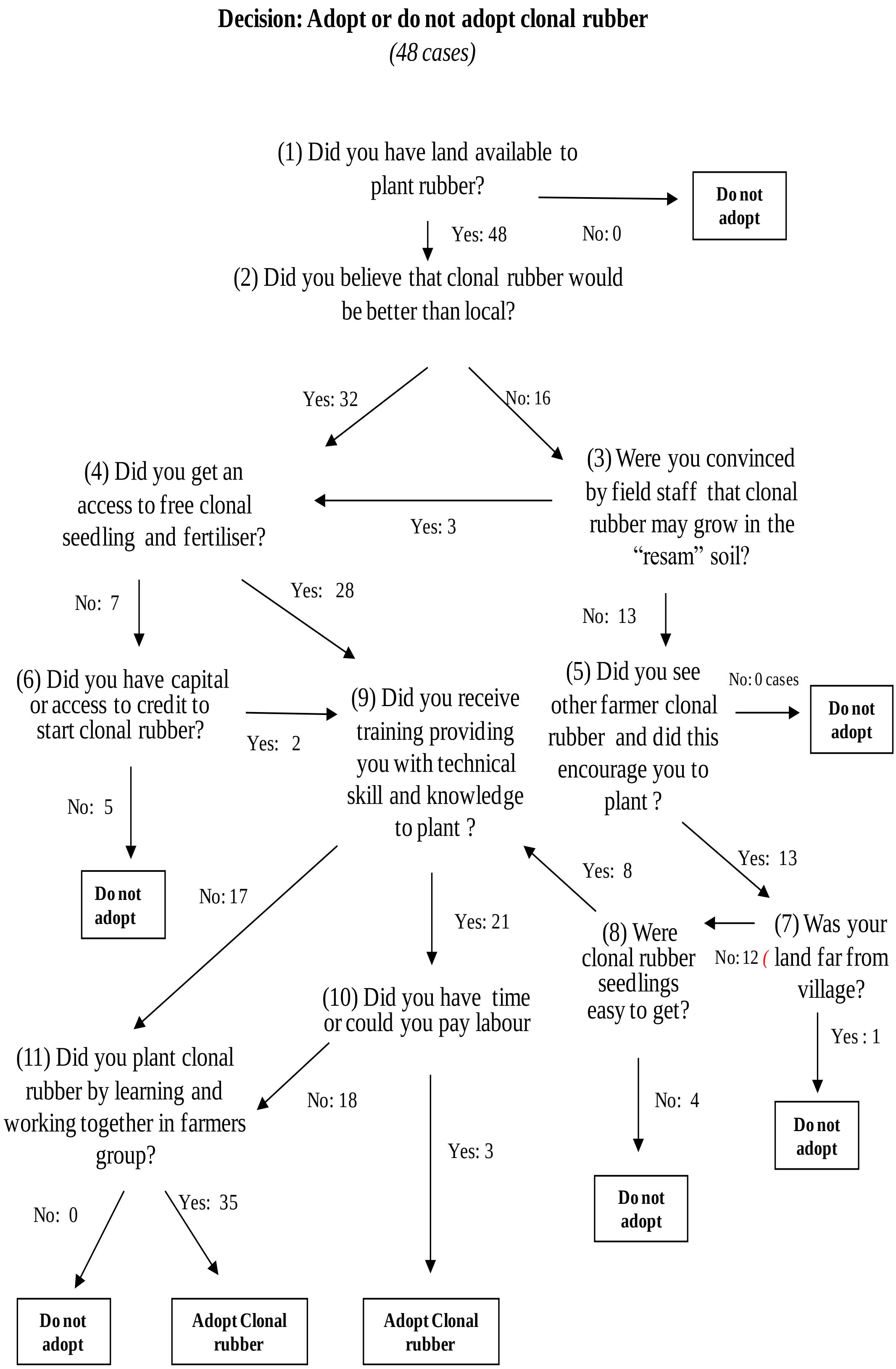


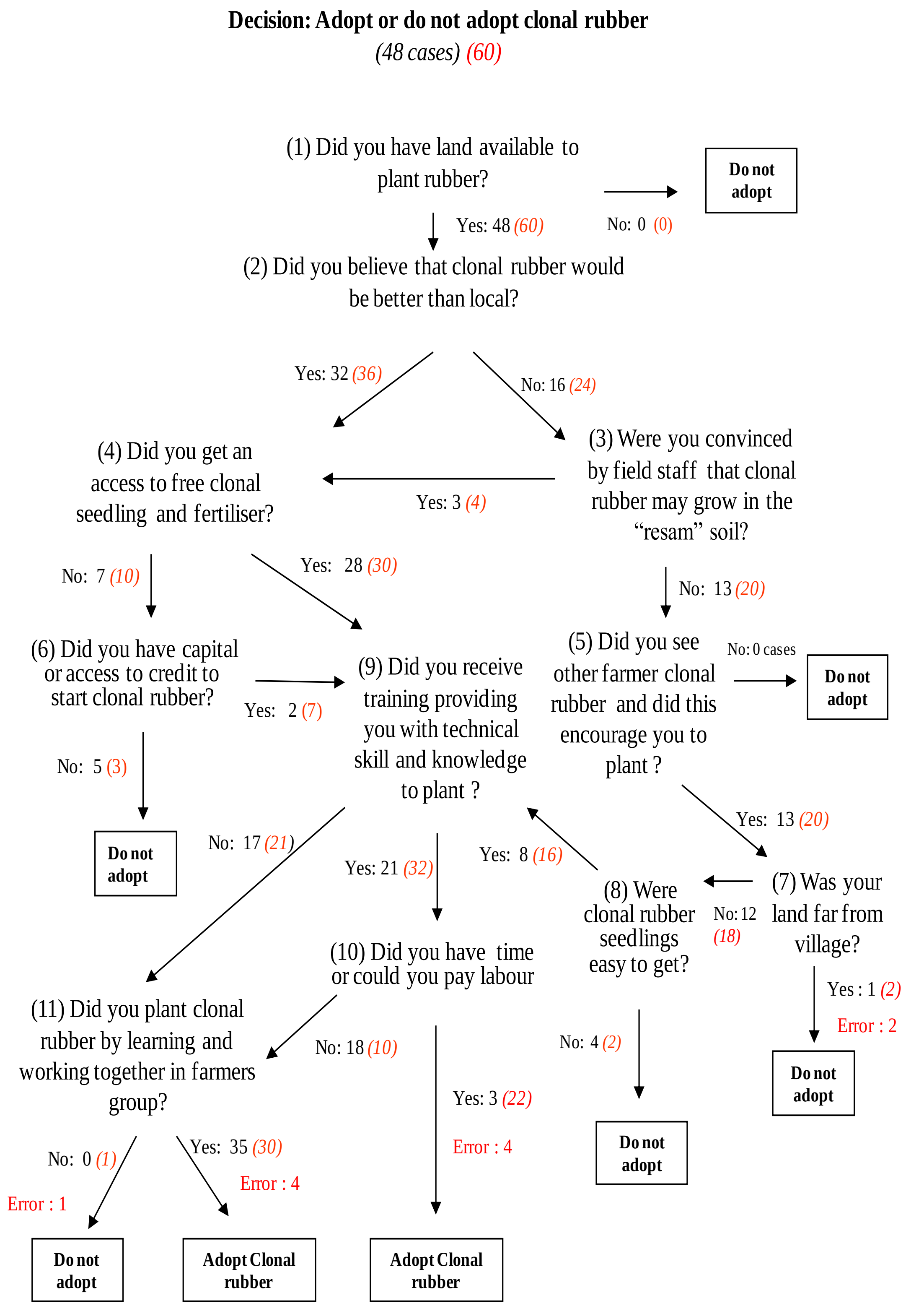
Figure 6.6 The decision tree model of adopting or not adopting of clonal rubber by smallholder farmers in West Kalimantan

From the decision tree the following criteria and constraints in the adoption of clonal rubber in West Kalimantan can be identified:

1. *Did you have land available to plant rubber?*
2. *Did you believe that clonal rubber would be better than local?*
3. *Were you convinced by field staff that clonal rubber may grow in resam soil?*
4. *Did you get access to free clonal seedlings and fertiliser?*
5. *Did you see other farmers grow clonal rubber and did this encourage you to plant clonal rubber?*
6. *Did you have capital or access to credit to start clonal rubber?*
7. *Was your land far from the village?*
8. *Were clonal rubber seedlings easy to get?*
9. *Did you receive training providing you with technical skill and knowledge to plant clonal rubber?*
10. *Did you have time or could you pay labour?*
11. *Did you plant clonal rubber by working and learning together in a farmers' group?*

6.3.2 Test of the Decision Tree Model

The objective of the test of the decision tree model and the methodology is the same as the testing procedures for Jambi (see Chapter 5, Part 5.4.3). The result of the testing of the decision tree model in West Kalimantan is shown in Figure 6.3.



Notes : (x) = criterion' number, (x) number of respondents from testing

Figure 6.7 The tested-decision tree model of adopting or not adopting of clonal rubber by smallholder farmers in West Kalimantan

The decision tree model that developed from the first interview in West Kalimantan was able to predict 50 farmers out of 60 farmers, as it made 11 errors. That meant it had an accuracy of 82%.

$$\text{Success rate} = \frac{\text{total number of successes}}{\text{Total number of cases}} = \frac{(60\text{-}11) \times 100\%}{60} = 82\%$$

There were three types of error in criteria 7, 10 and 11 and involved 11 cases. Two farmers who said yes to criterion 7 (their location far from the village) did adopt clonal rubber. Four farmers who said yes to criterion 10 which is they have time and could pay labour but they did not adopt clonal rubber. Four farmers who said yes to criterion 11 did not adopt, meanwhile one farmer who said no to this criteria did adopt clonal rubber.

6.3.3 How Rubber Farmers Made the Decision

The way rubber farmers came up with the decision to plant clonal rubber or not are explained below.

1. Rubber farmers were introduced to clonal rubber in a technology package including clonal seedlings, fertilisers and training by ICRAF. Before deciding to plant clonal rubber, the farmers had to have the basic requirements for establishing a rubber plantation, whether they had land available or not (criterion no (1). If they had land available there was a possibility for farmers to plant clonal rubber. All respondents had a piece of land of at least 0.5 hectares to plant rubber. Availability of land was usually in the form of old and unproductive jungle rubber, secondary forest, land full of *Imperata cylindrica*.

2. Farmers would not proceed to the next step unless they already know something about clonal rubber and believe that clonal rubber is potentially better than local rubber (criterion (2)). Some of the farmers who were introduced to clonal rubber by ICRAF already believed that clonal rubber was potentially better than local (32 respondents) as they observed from other farmers or government rubber estate. Other farmers did not know about it or not believe in it yet (16 respondents).

3. The farmers who said yes that clonal rubber would be better then continued to criterion (4) asking if they have got incentives. Of the thirty two respondents who believed in clonal rubber 28 of them got access to various incentives such as clonal seedlings, fertiliser or pesticides from ICRAF for establishment of demonstration plots. In the beginning they had a meeting at least once a week with assistance from the ICRAF staff. The farmers had incentives from ICRAF (free seedlings, fertiliser, herbicides) and assistance of technical knowledge to produce grafted clonal seedlings and planting, including plant distance, weeding, fertilising, pest and disease management and the tapping system. They adopted the protocol for clonal rubber.

4. Seven respondents who knew that clonal was better but had no access to clonal cannot adopt clonal then continued with criterion (6) if they have their own capital or access to credits. Five of respondents have no incentives and access to credit therefore they have difficulties to start clonal rubber and decided to not adopt clonal rubber. Two respondents continued to the next criterion (9) as they have capital and access to credit.

5. Thirty farmers who had capital (criterion 6) or incentives (criterion 4) and also the farmers who passed criterion (8) continued the process to criterion (9) getting the technical knowledge of planting and managing clonal rubber.

6. In the right side of decision tree, sixteen respondents who did not pass criterion (2) before contact with ICRAF were asked whether they were convinced by the researcher and field assistants (criterion 3) and three of them believed and wanted to try and then they went to the criterion of capital and training (criterion 4). Thirteen of the farmers who said no at this stage, criterion (3) then faced criterion (5). These farmers were waiting to see if the other farmers planted clonal rubber first and sought more information about clonal rubber. They have been encouraged by the growth of clonal rubber and move on to the next criterion (7).

7. The criterion (7) asked if the farmers have their parcel of land far from the village. One respondent rejected clonal rubber as he only had land available far from the village. He thought that he could not maintain his clonal rubber

intensively if it was far from his home, so he decided not to apply clonal rubber. The other 12 respondents continued to the next criterion (8).

8. The criterion (8) was whether clonal rubber seedlings were easy to get. Four respondents stopped the process of adopting clonal rubber as they had no access to clonal seedlings. The other eight respondents followed through other criterion (9).

9. Together with the farmers who passed the criteria no (4) and no (8), 38 farmers arrived at the stage of needing technical knowledge for planting and managing clonal rubber criterion (9). Twenty one farmers passed the criterion as they received formal training from ICRAF or local government in clonal rubber and continued to criterion (10). The other 17 of respondents who said no to receiving training continued to criterion (11) learning from other farmers via farmers' groups.

10. Twenty one respondents had the knowledge need to decide if they have time and labour. Three of them had their own capital and used hired labour and they made a final decision to adopt clonal rubber. Meanwhile, 18 others continued to criterion (11) and explored whether they could use collective labour and worked together in the establishment of clonal rubber. A total of 35 respondents on this side passed criterion (11) and they adopted clonal rubber.

6.4 Analysis of Decision Criteria

These are some decision criteria for farmers regarding adoption of new rubber system in Sanggau, West Kalimantan:

1. *Did you have land available to plant rubber?*

Availability of land was important in the adoption of clonal rubber in Sanggau. In recent times, land was one of the important issues in West Kalimantan, especially since oil palm plantation development has been intensified.

> I was thinking about planting rubber. For us, the very important factor was land; if I have land I want to try clonal rubber. So as long as land was available, I will plant clonal rubber (Non Adopter, Pana).

> I planted clonal rubber for my saving as I was getting old, but I cannot plant more as I have no land. I gave my land to my daughter and my son in law. I have also joined the oil plantation estate program, so I have to give 7 hectares of my land to the estate, and I will get 2 hectares of my own oil palm plantation, plus I have to pay credit for 15 years. I just maintain my 1 ha of clonal rubber (Adopter, Senunuk).

2. *Did you believe clonal rubber may increase your rubber yield?*

The farmers have received the information that clonal rubber potentially gives them better yield compared to local rubber. But usually they want to see for a fact that clonal rubber has better growth and yield. Farmers who believed tried clonal rubber after they saw the growth of clonal rubber in the demonstration plot. The farmers also had information from outside the village and they noticed that the growth of rubber trees was faster than local ones. Some respondents tried to harvest the latex of clonal rubber in year 5, as they wanted to know if clonal was faster to tap compared to local rubber.

> As I live in the village, I have heard information from other farmers that clonal rubber grows faster, and can be tapped faster as well, compared to local rubber for which we have to wait more than ten years. But it also depends on us for maintenance and if I have time I always go the rubber garden (Adopter, Pana).

> I have heard from other farmers in other villages, that clonal rubber has a higher yield, more that 11 kg from 200-300 rubber trees. I have heard from farmers from Sanjan Village who had travelled here, that clonal rubber makes the cup full, and sometimes more than one cup. I believe in it. But we have to tap with one day off, not intensively every day. The yield made me interested enough to plant clonal to change from the local ones. (Adopter, Senunuk).

3. *Were you convinced by field staff that clonal rubber may grow in resam soil?*

Some farmers did not believe that clonal rubber may grow in “resam” soil. This soil “resam” is characterised by domination of *Imperata cylindrica* in its fallow. The farmers believe this type of soil was poor and crops or trees planted in this type of soil have low growth and yield or even cannot grow. Most of the farmers did not believe that clonal rubber would grow in this soil. In the beginning, respondents were resistant to cultivating clonal rubber in the resam soil. However the field staff convinced them by introducing demonstration plots of clonal rubber with intensive fertilising and weeding systems in the resam soil. In reality resam soil has advantages compared to other land and it was suggested that they develop clonal rubber by using a semi intensive system. Some farmers were interested in planting as a trial on their farm.

> I did not believe before that clonal rubber would grow in resam soil. Local rubber could not grow in this type of soil before as it was resam soil. And I thought that will have the same effect on clonal rubber too. From the past we knew that resam soil was difficult to plant, especially for paddy rice and rubber too. But the field staff convinced me that with intensive maintenance such as regular weeding and fertilizing, the clonal rubber can grow better in resam soil (Adopter, Pana).

The farmers in Kalimantan have been motivated to adopt clonal rubber as they were convinced by the technical staff's expertise. Adopters believed and trusted the expertise and assistance of field staff. As the introduction of clonal rubber was new for rubber farmers, the role of extension and assistance in the field was very important. The farmers were confident in maintaining clonal rubber as they have field assistants in case they have a problem. The quality, relevance and accessibility of information were key factors in facilitating the rapid uptake of knowledge and technology.

4. *Did you get access to free clonal seedlings and fertiliser*

As clonal rubber was new and required more capital and labour, incentives had an important role for farmers to start to establish a clonal rubber plantation. The farmers were interested in getting incentives to start clonal rubber because most of the farmers had a lack of capital. At the beginning of the introduction of clonal rubber, the adopters in study sites were interested in planting clonal rubber as they were receiving incentives from the project. The incentives including clonal seedlings, fertiliser, pesticides and assistance attracted farmers to adopt clonal rubber. For poor farmers incentives were important and without them they could not afford the cost of the establishment of clonal rubber.

> I want to plant clonal rubber as I have heard the yield is better than the local, however I have no capital. I cannot afford the price of clonal rubber which was expensive. I cannot buy it at the high price, so it was better if there was an incentive for me. I have no capital to buy fertilizer as well; I can buy only 2-3 kg of fertilizer (Non Adopter, Pana).

> I planted a small amount of clonal rubber, around sixty. I received free clonal seedlings and I just planted those ones as I wanted to try them.

> But I did not maintain them intensively I just did what I usually I do to my local rubber. I wanted to plant more, as I heard that the clonal has a better yield than local, but I have no fertilizer, herbicides and I did not know how to propagate clonal rubber. (Non adopter, Senunuk)

5. *Did you see other farmers' clonal rubber and did this encourage you to plant clonal rubber?*

The farmers in West Kalimantan were interested in adopting after they had seen the demonstration plot or other farmers' clonal rubber plantations. They saw that the clonal rubber's growth was faster than local. The demonstration plots can be seen easily as they are not too far from the village road. Most of the participating farmers are keen to maintain clonal rubber by following RAS procedures. As a result most of the demonstration plots show the advantages of clonal rubber such as faster growth. Participating farmers in the project have mostly seen other clonal rubber plantation as they participated in training including field studies and are convinced by the evidence from demonstration plots. Demonstration plots in Pana village have an important role in the adoption of innovation.

> I was interested in planting clonal rubber since my relatives asked me to check their clonal rubber. I saw the clonal rubber's growth was faster than local. So, I was interested and joined with the ICRAF and I planted clonal rubber but in only small area. I want to continue to develop clonal rubber but I have no capital yet, especially to buy clonal seedlings, herbicides and fertilizer (adopter, Senunuk).

> I have seen clonal rubber growth and yield from other farmers who joined the ICRAF. I have seen demonstration plots close to the main road in the village. And I saw clonal rubber in other villages as well (Sanjan). The growth of the rubber trees was faster and the latex filled the bucket. I was interested in planting it and I want to make it a saving for my children when they are growing and need money to go to school (Adopter Senunuk).

The farmers made the decision to adopt clonal rubber after they have seen that clonal rubber was better in yield or growth compared to local, from demonstration plots or other farmers who have applied clonal rubber. They believe, based on their experiences of planting local rubber that clonal rubber grows faster than local. Most of them were motivated by the success of other farmers who have developed clonal rubber with ICRAF. They learnt from ICRAF's farmers how to maintain clonal rubber and they bought clonal seedlings from ICRAF's farmers as well.

6. Did you have capital or access to credit to start clonal rubber?

The introduction of clonal rubber in the Rubber Agroforestry System required more capital than the traditional system. The farmers expressed their concern with converting local seedlings to clonal by:

> I have no money to buy clonal seedlings or to buy fertilizer, I need money to buy herbicides as clonal should be planted in the area that is free from competition with other crops or "*Imperata*" (Non Adopter Embaong)

The farmer in West Kalimantan recognised the additional cost associated with the need to change some of their practices from traditional rubber extensive system to an intensive system which needs more labour and time. For example, herbicides were needed for weeding land in West Kalimantan which is invaded by *Imperata cylindrica* and the farmers were more likely to use herbicides rather than a manual system for weeding. Weeding manually seems less costly but it takes more time and labour.

7. Was your land far from village?

The remoteness of the area for rubber plantation was one criterion that influences the adoption of clonal rubber by smallholders. If the location of their rubber garden was far from their house, transportation was a problem for farmers. The clonal seedlings grow in polybags before planting in the field, whereas local seedlings can be planted directly from the stump. The farmers transported more than 100 stumps of local seedlings to the field at one time, in contrast they only transported around 50 clonal seedlings using a motorcycle. The farmers also have got difficulties to maintain regularly clonal rubber in a remote location. Regular control was needed as clonal rubber with high investment should be controlled regularly from attack by animals, infection by fungi and expansion of *Imperata* that can suppress the growth of immature clonal rubber.

8. Were clonal rubber seedlings easy to get?

Some farmers in Sanggau, at the beginning of the introduction of clonal rubber had a problem with lack of availability and access to clonal seedlings. Clonal seedlings were important in rubber cultivation as some clonal rubber in the traditional market cannot be guaranteed as pure clonal rubber. Pure clonal rubber seedlings were difficult to find at the village or sub district level because there were limited certified private nurseries which provide clonal seedlings. Lack of availability of guaranteed clonal rubber or if the price could not be afforded by rubber farmers becomes a constraint for farmers. Two farmers mentioned difficulties in getting pure clonal rubber seedlings below:

> I have planted clonal rubber when there were free clonal seedlings for every villager here. I received only 150 clonal seedlings, without fertilizer or herbicides or even assistance. I did not know how to cultivate and maintain them and I just planted them like local rubber, without proper distance or intensive maintenance. I saw other farmers who planted clonal and maintained it better and the result was good. I want to cultivate more but I have no clonal seedlings. There were traders who sell clonal seedlings, but I was not sure of the purity and no guarantee of pure clonal seedlings. I do not want to take a risk and be disappointed with the yield in the future, so I chose local rubber to cultivate (Non adopter, Senunuk).
>
> I have no plan to cultivate clonal rubber, as I have no clonal seedlings yet. In a private nursery I have to buy in big numbers as they do not provide a small number to sell. I have no money to buy, and what I want is just to buy a small number and I will add as I have more money. Fertilizers and herbicides are also expensive and difficult to get sometimes (Non adopter).

Clonal rubber was difficult to find before the project started. However in Sanggau West Kalimantan, after the projects have been running, nurseries also were growing and have become alternatives for farmers to create additional income. After receiving training that was held by ICRAF, some farmers started to produce their own clonal seedlings and some of them produced more seedlings for sale to other farmers. Nurseries became new businesses in Sanggau and Sintang districts, and they spread the seedlings to other villages or districts. In some villages like Pana and Senunuk, the farmers produced seedlings individually or as a farmers' group. They also produced seedlings to support their members and to supply local government for the project of clonal replanting. As there was competition among nurseries, the price of clonal rubber became more competitive.

9. *Did you receive training providing you with technical skill and knowledge to plant clonal rubber?*

Technical assistance was important for rubber farmers. Some of the farmers in Pana knew about clonal rubber from previous projects, but they did not have technical knowledge to plant clonal rubber as they did not get training. They were interested in joining the ICRAF project since there was an opportunity for them to learn more of the techniques of grafting, producing seedlings and maintaining a rubber garden to get a better yield. Full assistance in the field was also one of factors that made farmers want to join in the program because they wanted the knowledge for better cultivation. The previous projects were short term programs and there was less field assistance. Two of respondents from Pana Village cited:

> In the beginning many farmers thought that resam soil which was abundant in Pana would be not good for rubber, but the researcher from ICRAF told us that they will show us how to plant and they will assist us from the beginning till the end. I believe they have knowledge and experience in rubber, and they promise to show us other clonal rubber in other places for comparison. In the past we have never had assistance from the project, mostly we have just got the seedlings and we have had to plant and maintain them by ourselves (Adopter, Pana Village).

> I have been interested in clonal rubber as I have seen that the latex was better than traditional rubber. However I had no technical knowledge to plant clonal rubber until staff from the ICRAF gave us assistance and training. I also did not know how to get clonal seedlings before, if there were any, they would be very expensive. They taught us how to produce clonal rubber from planting materials that they gave to us. They promised to assist us and can discuss or consult if we have a problem (Adopter, Pana Village).

10. *Did you have time or could you pay labour?*

The availability of labour has an important role in the decision making process of the farmers in the adoption of clonal rubber. Since clonal rubber was more intensive in management compared to local, the farmers believe that for planting clonal rubber plantation they need more labour especially for weeding, fertilising, and spraying pesticides when needed.

> For local rubber I do not need to maintain it regularly, sometimes I do weeding but only once a year or never at all. I planted clonal rubber but now I have difficulty in maintaining it properly and I have no time and labor. I have to do tapping of local rubber as the main source of income, and I sometimes work as a part time worker in an oil palm plantation for additional income. I have no family to help me to work on clonal rubber, sometimes I ask my wife, but we have three small children to take care of (Adopter, Senunuk).

As mentioned before, most of the work in the rubber plantation in West Kalimantan was carried out by family labour and farmers who usually use paid labour include those farmers who have a large area of rubber and have enough capital to pay labour, have other off farm jobs such as a teacher, civil servant, soldier or businessman, as they mostly have no time to work in their rubber garden and farmers who were busy in an oil plantation job especially in the harvesting of oil palm season.

11. *Did you plant clonal rubber by working and learning together in a farmers' group?*

As lack of technical knowledge was a constraint, farmers in Pana and other villages in West Kalimantan worked together in farmers' groups. Once farmers have training or join the ICRAF project, they have to be involved in one of the new farmers' groups. They have the responsibility to deliver their knowledge to other members especially on how to produce clonal seedlings as well as to plant and maintain clonal rubber. Together with ICRAF field staff, farmers' groups become the media for learning and working together.

The farmers in West Kalimantan used farmers' groups for helping each other to establish clonal rubber gardens and to resolve labour limitations. They may develop their own clonal rubber by working together in farmers' groups using the traditional system called *pengarih* (see Chapter 4 part 4.2.2. point 5). Each farmer has his own opportunity to get help from other members to work in the rubber garden, but one day he has to help the other members in their own rubber gardens. Each member has his own turn but also he has a duty. This system helps farmers to reduce the problem of labour and capital. All members in farmers' groups participate in all steps of preparation for a rubber garden such as land clearing, digging holes for seedlings, planting, weeding and fertilising. This farmer's group was created by farmers based on traditional collective action and is more bottom up. The farmers who become members of farmers' groups tended to adopt clonal rubber as they received support in terms of technical knowledge and labour.

6.5 Summary

The decision tree for West Kalimantan shows that the farmers were eager to adopt clonal rubber when they believed that clonal rubber was more profitable compared to local rubber, as they intend to increase their income from rubber on their limited land. They were also motivated by incentives and access to credit, availability of clonal seedling and assistance from field researchers. The farmers in West Kalimantan were also supported by the role of a farmers' group in information exchange and providing labour. However some farmers who were interested to plant clonal rubber ended with the decision to not adopt as they faced constraints such as lack of capital and lack of time caused by off farm jobs and also lack of labour.

The decision tree model predicted 82% of accuracy for decision to adopt clonal rubber with 11 errors. An error in the testing of the decision tree happens when the farmers are predicted to adopt clonal rubber as they passed all criteria and constraints, but in the end they did not pass the constraints but did adopt clonal rubber. Based on Gladwin's criteria (1989a) the model for West Kalimantan is in a good range and it was reasonable in predicting decision making behaviour to adopt or not adopt clonal rubber in the case of West Kalimantan.

Chapter 7 Discussion

7.1 Introduction

This section discusses the decision criteria in the adoption of clonal rubber presented in the ethnographic decision tree models in Chapters 5 and 6. The chapter begins with discussion of the decision criteria used by rubber farmers in their adoption of clonal rubber. This part also compares the decision criteria between Jambi and West Kalimantan in connection with the other studies mentioned in the literature review. All decision criteria are categorised into general key criteria, namely economic criteria, managerial criteria, technical criteria, and social structure, and policy and institutional.

7.2 Analysis of Decision Criteria of Jambi and West Kalimantan

The ethnographic decision tree modelling approach in Jambi (Chapter 5 and West Kalimantan (Chapter 6) gave an explanation of the farmers' decision making process and considered all key factors mentioned by the farmers. From the decision trees, it was found that the farmers used decision criteria in adoption of clonal rubber related to: economic criteria, managerial, technical criteria, social structure and policy and institutions. These factors can be categorised as is shown in Table 7.1.

Table 7.1 Summary of the decision criteria of Jambi and West Kalimantan

	Categorisation		Factors from decision criteria
A	Economic criteria	1	Availability of Land
		2	Expected profit increase
		3	Capital (cash)
		4	Risks and uncertainty
B	Managerial criteria	5	Labour
C	Technical criteria	6	Technical knowledge
		7	Information exchange
		8	Demonstration plot (observability)
D	Social structure and activity	9	Farmers group
E	Policy & Institution criteria	10	Incentives and credit
		11	Access to clonal seedling
		12	The role of Government and NGOs

7.2.1 Economic Factors

1. Availability of Land

Availability of land plays an important role in farmers' decision regarding the adoption of clonal rubber. Land is basic to cultivation of rubber and the farmers need to have at least 0.5 ha to start planting clonal rubber. When the farmers choose clonal rubber, they have to have spare land with productive local rubber or other commodities to support them during the immature period of clonal rubber. Most of the farmers who have decided to adopt clonal rubber have productive local rubber or other off farm jobs as income sources for their household.

In terms of land availability, both Jambi and West Kalimantan have the situation in which land is scarce. Figure 7.1 shows that most of the farmers occupied land less than five hectares - 65% in Jambi and 83% in West Kalimantan. In this case 12 % and 6% of farmers have less than 1 hectare in Jambi and West Kalimantan respectively. On average, farmers in Jambi have more land compared to West Kalimantan. As seen from Figure 7.1 ownership of the land in West Kalimantan was relatively less than in Jambi. Land scarcity is a less important issue in Jambi than

West Kalimantan but landholding is an important factor in the adoption of new technology in agriculture.

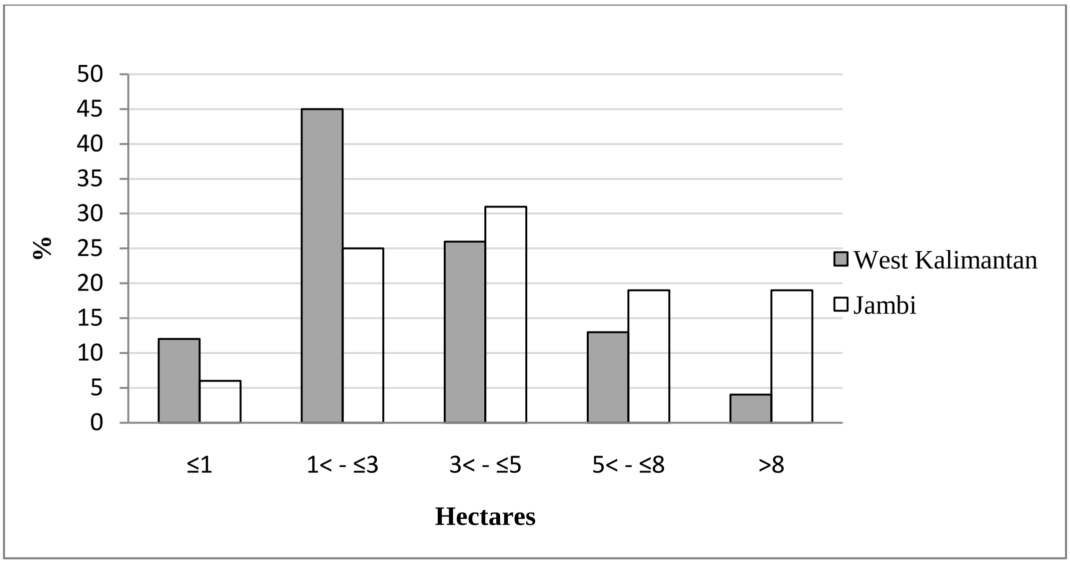


Figure 7.1 Land ownership in Jambi and West Kalimantan

In general, both places have demographic issues such as population increase caused by more births and also accelerated by the Government's program of transmigration[1] and oil palm development. With an increasing population, parcels of land belonging to farmers become smaller as they have to share with their children. As the farmers were worried about the future of their children and wanted to make it secure, they gave each child a piece of land even though it was small in size. In addition, transmigration programs in some areas in Jambi and West Kalimantan mean original farmers in this area have to share this land with farmers who came from Java.

Development of oil plantations in Jambi was also one of the factors that decreased the land available for rubber. When this study was conducted, an oil palm plantation was in the process of initiation, even though some farmers have been starting to become interested in oil palm. However, in Rantau Pandan oil palm has been developed in the upland areas where rubber agroforest was usually established. In Sepunggur village some areas of old rubber jungle have been converted to oil plantation. These development programmes of oil plantation are usually developed

[1] Transmigration is a program that intends to move people from densely populated land such as Java, Madura and Bali to the less populated area in the outer islands of Indonesia such as Kalimantan and Sumatra.

by big private estates that have been permitted based on licenses from the local government.

Also there were increased mining activities that reduced the opportunity to expand rubber agroforest such as coal mining. For example Rantau Pandan Sub District, Bungo, has 14,481 ha of good quality coal deposit and 6,481 ha of this has been exploited. The local government attracted international investors to exploit coal deposits in forest and land area in Bungo with production set to reach 60,000 – 180,000 tonnes per month. This was particularly the case under the decentralisation[2] programme, for local economic development, where the local government must finance their development based on their own natural resources.

In West Kalimantan, expansion of oil plantation has been faster than in Jambi. In the villages of Senunuk, Pana and Kopar, farmers who owned a large area of land or who have land close or in the area of establishment of oil plantation also planted oil palm besides clonal rubber. They used mostly unproductive land, secondary forest, old jungle rubber and land far from their home for oil palm. However in the other villages such as those reported by Potter (2004) in her study in Sanggau; some of the farmers have allowed their productive rubber and their tembawang to be converted to oil palm plantation. They were convinced by companies that their future lies with oil palm plantation. However most of the farmers in Jambi and West Kalimantan kept their productive rubber as their main commodity and income source and they identified themselves as rubber farmer and have more confidence in rubber cultivation. Also rubber planting in Sumatra and Kalimantan was important for their land tenure security (Otsukaa et al., 2001).

Rubber planting in Sumatra and Kalimantan contributes to risk reduction and risk management in the face of the need to secure rights of land tenure and use under these institutional rules. The traditional system in Jambi and West Kalimantan was

[2] Decentralization is one of the most important reforms the Indonesian government has undertaken since the democratic elections of June 1999. Under new Indonesian Laws which provide the framework for political and financial devolution, the districts and cities are assuming new responsibilities that were previously covered by the national government, as well as managing new financial resources that have been transferred from the central government or raised within their own localities.

still used for legal ownership. The ownership was based on the marking of trees that they planted in the area which were recognised by neighbours, other farmers or the village leader. As inherited land it is usually recognised by their family. In their traditional system the farmers who opened land and planted trees including rubber became the owners of the land, so rubber trees were ideal markers of ownership.

With an increasing population, transmigration and conversion of land to oil palm plantation, the land for rubber cultivation becomes smaller; therefore the farmers need to optimise the land. One of the alternatives was they decided to adopt and cultivate high yield rubber to maximise the yield. This criterion is compatible with the statement that increasing land pressures such as from population increases lead the farmers to land use intensification by adopting new innovation (Scherr, 1995).

2. Expected profit increase

The decision tree shows that the criterion of belief that clonal rubber will be better than local rubber in terms of growth and yield was applied by farmers in both locations. This criterion related to the objective of farmers who planted rubber. Figure 7.2 shows that both groups of farmers have the same main objective of planting rubber as their main source of income and rubber has a very important role to fulfil in their daily life. The farmers who depend on the rubber as their main source of income will be very careful in making decisions which change their rubber garden. Rationally they will always try to increase production and profitability of their rubber.

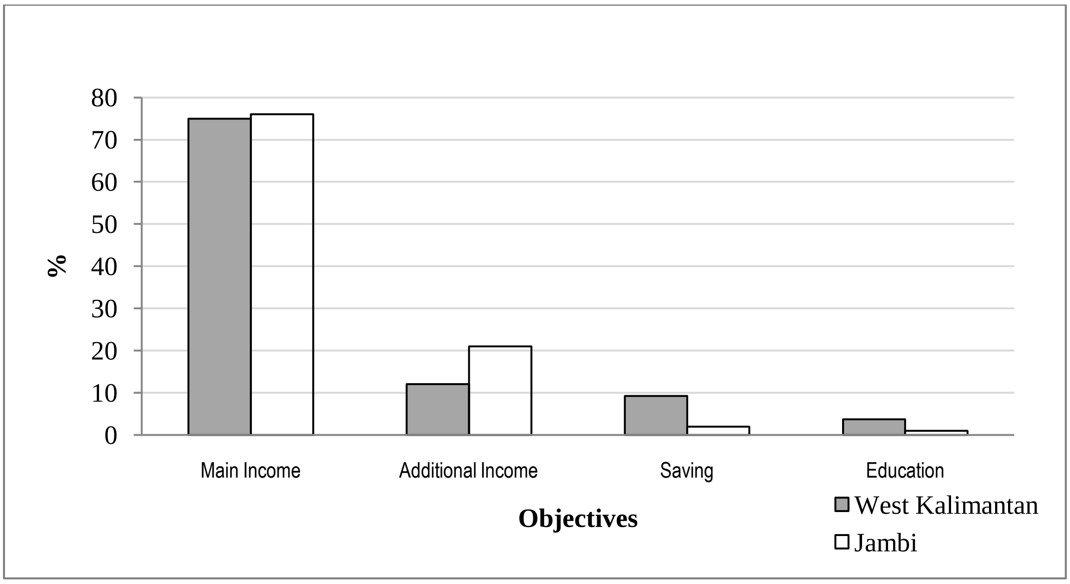


Figure 7.2 The objective of farmers planting clonal rubber in Jambi and West Kalimantan

The main motivation of farmers to choose clonal rubber was to increase their income to support their household and to improve their livelihood. They need more income in order to, for example, fulfil their household needs, to send their children to high school, spend on health and other needs such as renovating their homes and buying motorcycles. The farmers mentioned the importance of their additional income to send their children to better quality schools that were only available in other cities as they wanted their children to have a better life rather than follow them to become rubber farmers. Therefore, clonal rubber will be adopted by farmers if it is profitable compared to the old system.

The farmers in Jambi expect that planted clonal rubber will increase the yield of rubber, as they have heard clonal rubber is "*unggul*" (best in term of growth and yield). They received this information from ICRAF' staffs, previous projects or observation of other villages. Some adopting farmers who have known the potential yield of clonal rubber do not need much information to be convinced compared to those who hold less favourable beliefs.

In West Kalimantan, expectation of higher profits is also the main reason for farmers' adoption of clonal rubber. The farmers want to maximise utilisation of land as land becomes scarcer and they have less chance to expand their land from forest and secondary forest. The forest land has been converted to forest plantation, oil palm plantation, transmigration or other local government development programs. Getting more yield and more profit in order to increase their income seems to be the main reasons for farmers to change from local rubber to clonal rubber. It was the same case when oil palm plantation was introduced to them. The farmers have seen the opportunity to get more income from oil palm. Some of the farmers were interested in planting oil palm because farmers can get the results faster than rubber or they are convinced by oil palm companies.

The farmers' expectations of getting yield increases and more income from clonal rubber have positively influenced the adoption of clonal rubber. Holding a positive expectation of better profit from clonal rubber is important, especially in the beginning of the adoption process (Katungi, 2007). With time, potential adopters increase their belief with information and observation from other adopters and hence they are encouraged to adopt. For example farmers' positive perceptions of agroforestry have had significant positive effects on the adoption of agroforestry in India (Neupane et al., 2002. This finding is also supported by the other studies that showed the importance of farmers' positive perception and belief that new technologies will be better than existing systems (Amsalu and de Graaff, 2007; Gladwin, 1979; Mercer, 2004; Rajasekharan and Veeraputhran, 2002; Vanclay, 2004). A study with farm forestry projects in India pointed out that farmers grow trees on their land if tree growing is more profitable than growing any other crops (Balooni and Singh, 1997).

3. Capital

The adoption of clonal rubber is also affected by inputs or capital. Decision tree models show ten respondents in Jambi and six in West Kalimantan did not pass this criterion as they had no incentives and had no capital to start clonal rubber and therefore did not adopt clonal rubber. This was mainly because the establishment of clonal rubber plantation requires more cost, labour and inputs compared to the development of local rubber. As mentioned earlier in chapter 5 part 5.4 investment in establishment of clonal rubber is needed for buying clonal seedlings, fencing, weeding and applying fertiliser that should be done regularly. Additional cash is needed for surviving during the waiting period when rubber was in immature periods, especially for farmers who have no additional income. One of the farmers mentioned that clonal rubber was only for rich farmers who have cash to start clonal rubber and they can survive during the waiting period as they have secure income every month for their daily livelihood. They compared this to cultivation of local rubber as they did not need much capital to establish a local rubber garden.

One of the characteristics of smallholders is lack of capital. Figure 7.3 shows most of the farmers have gross annual income in average between IDR 10 million – 30 million (or equal US$ 1000 – 3000).

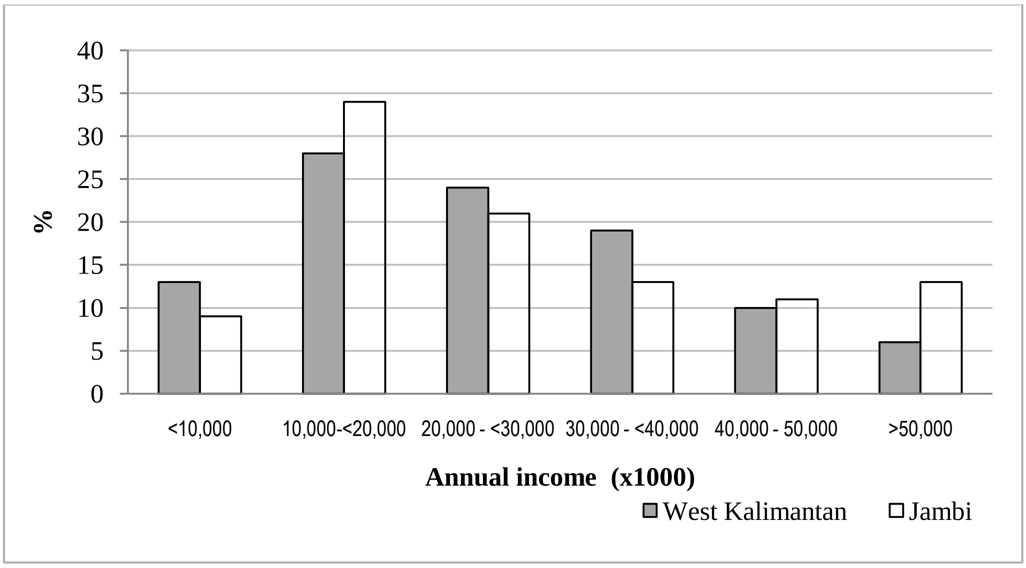


Figure 7.3 Gross annual income of respondents in Jambi and West Kalimantan

Capital has long been acknowledged as an obstacle in adoption (Feder et al., 1985). The ability of clonal rubber to increase yield is characterised by increased input (improved seedlings, fertilisers, herbicides, pesticides) and more intensive farming. In the studies by Supriadi and Chamala (1998) in Sumatra and Sail and Muhammad (1994) in Malaysia, they found that farmers did not adopt rubber technologies as they lack sufficient funds to start new system.

4. *Risks and uncertainty (pest & diseases)*

The decision tree in Jambi shows that the farmers are concerned about the risk and uncertainty of planting clonal rubber. The farmers in Jambi who have high dependence on jungle rubber and have had long periods tending jungle rubber still believe that local rubber will live longer. They believe local rubber can reach the age of 50 -100 years and can be tapped for more than 30 years. As they have seen very old rubber in the jungle that is still alive and productive they believe that local rubber that has been planted by their ancestors was more adaptable to their environment and soil conditions.

However, from the interviews it was found the concept of longer age in farmers' perceptions was different from the researchers' point of view:

a. Rubber trees were mostly tapped at the age of 10-15 years compared to clonal at 5-7 years of age, and so they possibly live longer,

b. Rubber trees in plantations live longer than as individual rubber trees. Farmers planted more than 500 trees in one hectare without a uniform distances between trees. As there was limited labour farmers tap only part of the rubber trees and tap the other rubber trees later, so they might continue to tap different trees in the same area longer

c. In the traditional local rubber system, the farmers usually plant more trees per hectare. Farmers allow the natural succession of rubber trees. Each dead rubber plant was replaced with a seedling that grows naturally around the old rubber tree or they plant local seedlings between mature rubber trees. This system is called "sisipan" (Joshi et al., 2003) in which they plant new young local rubber plants in the areas where plants have died. This makes it difficult for farmers to keep track of the age of individual trees.

From research evidence, clonal rubber can grow to 36 years old and the rubber can be exploited for 25-30 years (Delabare and Serier, 2000). However, this age and length of production of rubber depends on the clonal selected, climatic conditions and the most important factor is the management practises of rubber farmers (Delabare and Serier, 2000). Some pests and disease affect growth and production of rubber such as root diseases including white root fungi and leaf diseases. Therefore, intensive management in selecting planting materials, fertilising, weeding, pests and diseases treatment and tapping are important factors in successful growth and yield of rubber.

From the observations and study of literature, the causes of shorter life and production of clonal rubber can be linked to three main causes, namely pests, diseases and over exploitation.

1. *Pest*

   Pests (wild pigs and monkeys) were a problem for the rubber farmers, especially in the area of Rantau Pandan, Sepunggur and Lubuk Kayu Aro. The pigs like to crush the roots of rubber seedlings, to dig the soil surrounding the seedlings to find bugs or to scratch their bodies on the seedlings. As a result the seedlings become damaged or broken. Williams (2000) and Joshi et.al (2003) in their research also noted that pigs were a problem in establishing clonal rubber.

   This situation was different in West Kalimantan where the environment, religion and culture are different to Jambi. For example they have no problem with wild pig and monkey. In Sanggau, most of the farmers are Christian and they were allowed to consume pork. Most people farm pigs for home consumption or ceremonial tradition. They keep the animals close to their home or part of their home or keep them in a cage in their rubber garden. In West Kalimantan the farmers did not need to fence their rubber garden.

Figure 7.1 Pigs as animal husbandry associated with rubber in West Kalimantan

2. *Diseases and Imperata cylindrica*

   Another factor in their decision was that farmers believe that clonal rubber was less resistant to diseases and some of the fungi, such as white root fungi they believe may attack and destroy their rubber. In Sanggau some of clonal rubber demonstration plots those were damaged by white root fungi. In Sanggau constraints were *Imperata cylindrica* as well as white root fungi. *Imperata* growth surrounding immature rubber may reduce the growth of rubber. The farmers have to eradicate *Imperata* to reduce competition with the growth of young rubber but this was not a problem in Jambi.

3. *Over exploitation*

   Clonal rubber also was damaged because of over exploitation. Ideally, based on the protocol clonal rubber trees should be tapped a maximum of 3-4 times a week and also tapping was not recommended during or after rainy days. However, to maximise the yield most of the farmers do tapping every day similar to tapping system for local rubber. Field observations in Jambi found that tapping practices in smallholdings were very high intensity and harmful with bark damage dropping overall rubber yield. As a result a lot of rubber trees became unproductive and short lived.

   The smallholder farmers have a habit of tapping every day when weather is permitting because of socio economic reasons (Gordon, 2004). The farmers in Jambi mentioned that the main reason was to maximise results in order to pay off credit on new items such as a new motorcycle. With the promise of increased latex production from clonal rubber trees and the increase in the price for latex some farmers bought motorcycles and paid for them on credit. Mostly they have no other income sources except the yield from their clonal rubber trees. For this reason the protocol for tapping latex mostly did not work.

As clonal rubber was new for rubber farmers, it is likely to have some risks and uncertainty factors. New technologies can have subjective risks and the farmer's perception of riskiness has an important influence on adoption decisions (Feder and

O'Mara, 1981; Ghadim et al., 2005; Shiferaw et al., 2009). An innovation such as clonal rubber has some risks that farmers have been aware of. From the view of perception of risk and uncertainty, establishment of clonal rubber in West Kalimantan is less risky compared to Jambi which has more pests as constraints to plant clonal rubber. From observation it can be reported that most of the farmers still have two types of rubber plantations, clonal and local. The farmers keep two types in order to reduce their risk if their clonal rubber failed. At the beginning most farmers try to plant clonal rubber in a variety of hectare sizes, but mostly they cultivate it in small areas such as 0.5 ha. A study by Subejo (2000) in Indonesia shows that in terms of the adoption of new crops most farmers (77%) usually started with planting on a small scale.

As another way to reduce the risks, the farmers in Jambi used fences and guarded their rubber garden. Most of the farmers in Jambi did not want to adopt clonal rubber as they did not want to take the risk that their expensive clonal rubber investment will be destroyed by wild pigs. The non adopter farmers tend to plant local rubber as there is less risk of pests compared to clonal rubber. These constraints and risks were recognised by farmers when they were going to make the decision to plant clonal rubber. In their traditional way of farming, the farmers try to reduce the risk by modifying the cultivation system using their local knowledge. For example, they plant taller and bigger rubber stumps or seedlings to avoid wild pig attacks. The farmers allow wild crops or grass to hide the seedlings from wild pigs, along with fencing and increasing the monitoring and guarding of clonal rubber. To control these pests for clonal rubber the farmers usually fence off their rubber area, using local material such as bamboo or wood or material such as plastic or metal wire. They have to do fencing at the beginning of the establishment of clonal rubber and during the immature period 0-3 years. However, in some villages around Muara Bungo, young plants were found to be broken, by both pigs and monkeys, even though those plots were fenced (Williams et al., 2001).

Staying in the garden was the best way to protect the garden from pigs and monkeys. The farmer builds a shelter in the rubber garden and shares the task of guarding of the area 24 hours a day with other family members. As the farmers have to pay more for seedlings, fencing, weeding and fertilising, every single rubber tree becomes important and has high value. However, because of the location in a remote area, the farmers tend to spend less time in and rarely visited their rubber gardens. Protecting the garden from pests while the rubber plants are immature was a major constraint discouraging farmers from adopting clonal rubber. These mean additional costs, labour and time, in the establishment and maintenance of rubber gardens. For these reasons some of them cannot afford to plant clonal rubber as they thought it too risky and costly.

7.2.2 Managerial Criteria

Labour was an important criteria in the establishment and maintenance of clonal rubber. As it was an intensive system, a clonal rubber garden was characterised by more labour being needed for providing clonal seedlings, planting, weeding and fertilising. The availability of labour to be involved in clonal rubber plantation depends on the family size that can be utilised in clonal rubber gardens and the availability of paid labour and collective labour. As can be seen from Figure 7.5 family labour was still the main source of labour in both locations of study to establish and manage rubber gardens.

Figure 7.2 Sources of labour in a rubber garden

As can be seen in Figures 7.6 and 7.7 farmers in both Jambi and West Kalimantan have limited numbers of family members working in their rubber garden. Most of the family in both locations (60-65%) have only two family labourers, usually husband and wife.

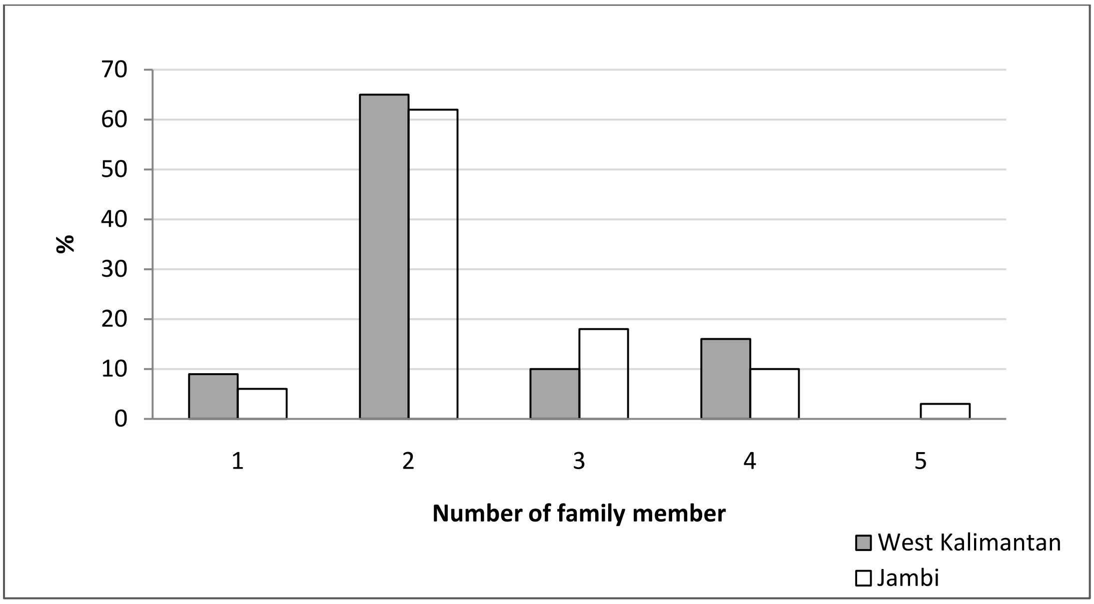


Figure 7.3 Numbers of family members working in rubber gardens

Lack of labour was mentioned by the farmers as one important constraint in the adoption of clonal rubber and was mostly due to small family size with young children in the family. Most of the farmers have 3-4 family members in their households (more than 50%) and only 30% have 5-6 members (see Figure 7.7).

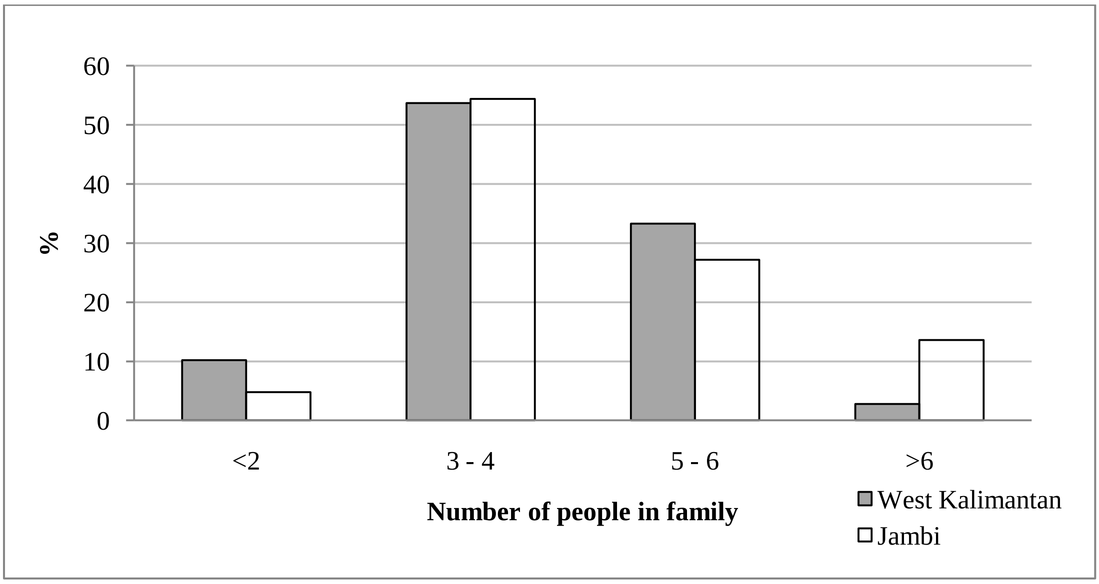


Figure 7.4 Numbers of people in family

In Jambi family labour was the main labour for establishment of a rubber garden. The traditional systems of sharing labour in Jambi such *Pelerin, berselang* and farmers' groups were not working. These traditional collective labour systems were only working for wetland paddy rice where the farmers can work together or other collective activities (see part 4.2.2. point 5). However they did not transfer to clonal rubber which was seen as an individual activity. The other potential for sharing labour was in a farmers' group, which was formally created by the government to communicate projects. However, the farmers' groups in Jambi mostly did not work to provide labour to establish a clonal rubber garden. Therefore, the source of labour was only the family and paid labour. The farmers have their own perception that cultivation of rubber was more individualistic rather than working in a group and each farmer was responsible for his own parcel of land including management of labour.

Data from West Kalimantan shows that family labour was followed by a combination of family and collective labour as the main sources of labour. The collective action related to activities in rubber agroforest establishment in the study area such as *pengarih* and farmers' group were available and helping farmers in providing labour for establishment. Most respondents thought it was difficult to establish a clonal rubber garden without working in a group because of the amount of work for preparation. A combination of family labour, paid labour and collective labour in West Kalimantan remain important components in the labour investment in the establishment of clonal rubber.

Labour constraint was found as a determinant of adoption of agroforestry in many studies. The availability of family labour was an important variable, which influenced the adoption decision and the non availability of family labour became a constraint in the adoption of rubber agroforestry technology systems in India (Rajasekharan and Veeraputhran, 2002; Viswanathan and Shivakoti, 2008). Sail and Muhamad (1994) in their research in Malaysia found that labour became a constraint in the adoption of rubber technologies as most of the smallholders were too old and weak physically to practise intensive labour. Study in Sumatra also showed that inadequate labour was one of the barriers to implementing the rubber technologies, therefore the adoption of intensive rubber practice was low (Haggith et al., 2003; Supriadi and Chamala, 1998).

7.2.3 Technical criteria

1. Technical knowledge

The decision tree of Jambi shows that technical knowledge becomes one of the criteria for the adoption of clonal rubber. Non adopters in Jambi mentioned that planting and managing clonal rubber was difficult to follow in some parts and more complicated compared to managing jungle rubber. Some differences such as managing clonal seedlings, fencing, applying planting distances, regular weeding and fertilising, and management of pests and diseases and applying a different tapping system have already been discussed. Some farmers also mentioned that with adopted clonal rubber they have to work harder transporting clonal rubber from home to the field and doing regular checks. For these reasons they did not want to adopt clonal rubber and preferred to continue planting local rubber, especially if they have been involved in jungle rubber practises for a long time. However some of the farmers have a feeling of complication of planting clonal rubber because they have less accurate information about planting clonal rubber. They lack practical knowledge of how to cultivate clonal rubber.

Lack of technical knowledge of planting clonal rubber prevents farmers from getting started. Most of the adopters in Jambi were the farmers who have had training. Meanwhile, some of the farmers who had heard about the potential of clonal rubber were interested in planting clonal rubber, but they did not know how to establish and manage a clonal rubber garden and so decided to cultivate local rubber. Training to transfer the new knowledge to the farmers and to improve their technical skills is a very important factor in the adoption of new technology. As reported by Ilahang et al (2006), ICRAF and also Dishutbun have carried out a sequence of training in Jambi and West Kalimantan (see chapter 2 part 2.6). This training covered technical and social training material such as grafting technique, nursery management, disease management, tapping technique, planting and farmer organization. Figure 7.8 shows the percentage of the respondents in Jambi and West Kalimantan experiencing training related to clonal rubber management.

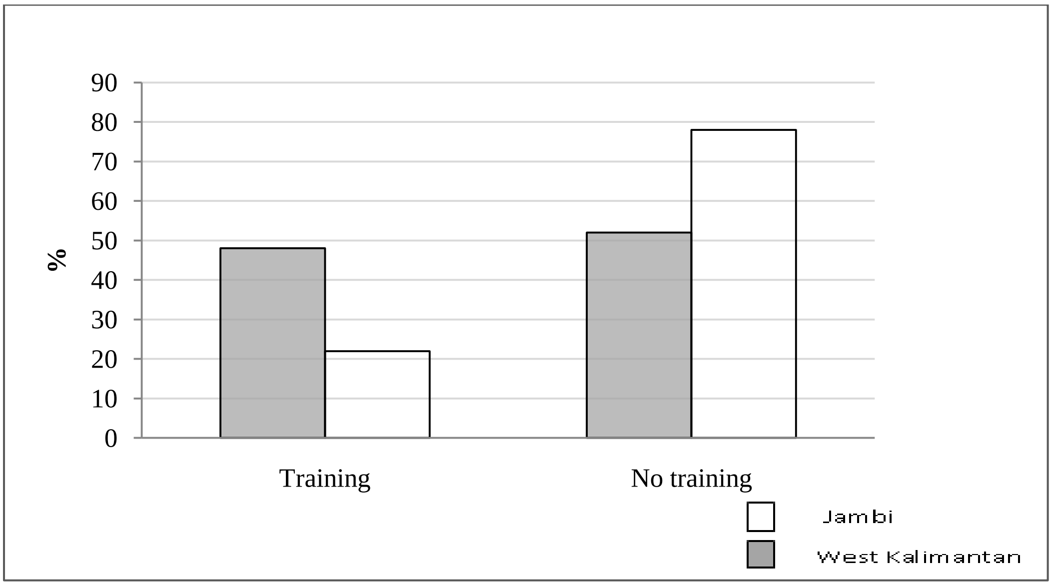


Figure 7.5 Farmers' experience of training

As can be seen from Figure 7.8., the respondent farmers in West Kalimantan have more access to training than in Jambi. The training was provided by ICRAF, local government and NGO. Ilahang et.al (2006) reported that in 2004-2005 a total of nine training sessions in Sanggau (Kalimantan) and five training sessions in Bungo (Jambi) were conducted and these were attended by a total of 671 participants. These institutions can support each other providing training programs so they may have covered more farmers. In addition, the farmers who have training in West Kalimantan were encouraged to teach other farmers the technical knowledge of clonal rubber in their farmer group. Further, these participant farmers who were trained and were involved in the farmers' group spread their knowledge by teaching other farmers outside the group. In the case of adoption of Integrated Pest Management (IPM) in Java, Indonesia, Feder and Savastano (2006) found that the trained farmers could serve as nodes of knowledge diffusion to the untrained farmers. In this study, the knowledge diffusion of clonal rubber became a horizontal process by farmer to-farmer interaction.

As a result, the availability of farmers' groups to support labour and the learning process means farmers are more likely to adopt clonal rubber for their land. Some of them developed a clonal rubber nursery on farmers' group bases and this increased to become a nursery business. Some farmers from Pana village with training in nursery management successfully developed their own nursery to fulfil their need for clonal seedlings as well as to sell to other farmers in the village. The group nurseries were even able to supply good quality planting material to the local government in 2006 for their smallholder rubber development support program (Ilahang et al., 2006). In West Kalimantan, following-up the training activities, field staff assisted farmers by regularly setting up meetings and working together in the farmers' group. Field staff evaluated the ongoing activities of the application of training and helped farmers to apply them in their own land. This could happen as the farmers have a close interaction with ICRAF staff and they were proactive to learn from ICRAF project farmers. However, in the case of Jambi, more farmers lack technical knowledge of the new practices. The process of farmer to farmer transmission of information also did not develop as the farmers mostly work individually in management of their rubber garden.

This lack of information and technical knowledge about implementation of clonal rubber was an important barrier to adoption especially if the farmers thought that new practices were difficult to put into practice. This situation of lack of knowledge causing less adoption of new practices also happened in case studies in Bangladesh (Chowdhury and Ray, 2009), Iran (Samiee et al., 2009) and Indonesia (Supriadi and Chamala, 1992). Farmers who have no confidence to apply new practice tend to make a decision not to adopt clonal rubber. The other cause of lack of technical knowledge in planting clonal rubber was related to information exchange. Training to transfer the new knowledge to the farmers and to improve their technical skills is a very important factor in the adoption of new technology. In their study Ilahang et al. (2006) shows that there were more farmers in West Kalimantan who applied their new knowledge of rubber about establishment techniques from the training rather than farmers in Jambi. The technical training had a more positive impact on improving farmers' knowledge and skills than just receiving information as all the project participants had knowledge that was needed to apply clonal rubber in their land. The farmers in Jambi and West Kalimantan who were trained were more likely to adopt the technologies than those who are not.

2. *Information exchange*

The other cause of lack of technical knowledge in planting clonal rubber is related to information exchange. The role of information exchange that can reduce lack of technical knowledge of clonal rubber is very important. In order to make decisions in adoption of clonal rubber, the farmers are exposed to multiple sources of information. The farmers in Jambi and West Kalimantan obtained information about clonal rubber from different sources of information that were available in their village. The sources of information were mainly based on formal sources (local government, researcher, extension worker, village leader, NGO) and informal sources (family, relatives, neighbours, other farmers, traditional farmers' groups). The sources of information are shown in Figure 7.9.

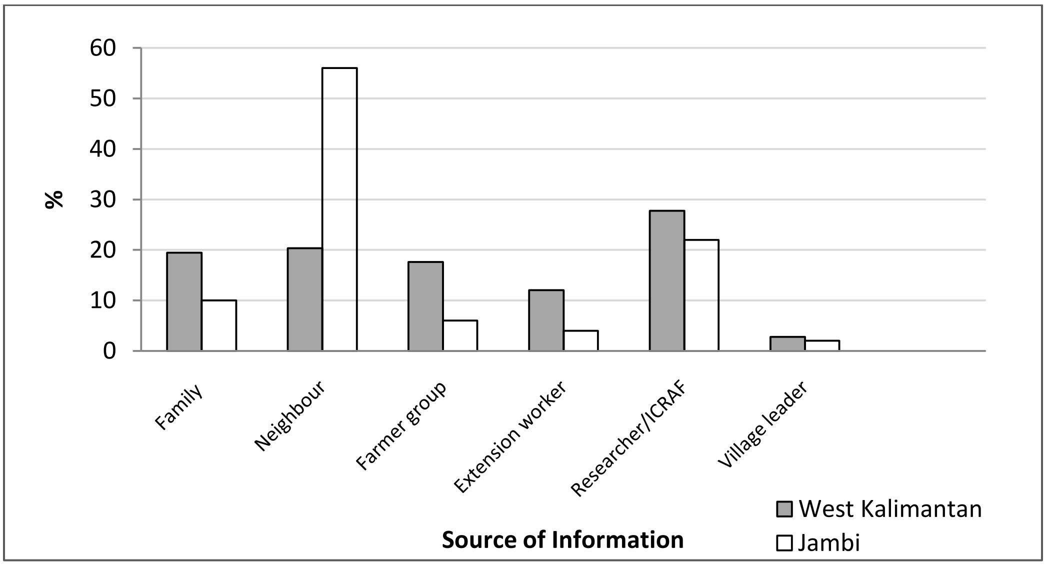


Figure 7.6 Sources of information on clonal rubber in Jambi and West Kalimantan

The main information sources in Jambi were other farmers, neighbours, followed by researchers, extension workers and family. It is shown in Figure 7.9 that the field researcher was much less important than neighbouring farmers to get information about clonal rubber (55% compared with 22% in Jambi). Other farmers received information from researchers, village leaders, extension workers and a small number from the media. The farmers gather information actively in an informal way from each other, neighbours and family to increase their knowledge.

Meanwhile, most of the farmers in West Kalimantan obtained their information through field researchers and extension workers. They considered field assistants were their main source of information about clonal rubber and other information related to rubber cultivation and they are recognised as important information sources. The field researcher provided assistance to the farmers regularly and continually. It was mentioned by farmers that field assistance committed to assist the farmers started from the discussion for the establishment of the field trial until the first tapping of the rubber yield. Extension workers employed by the government also have an important role, not only based on their regular availability in the field, but also on their contribution to supporting the ICRAF. Extension workers in the case of Pana, for example, became early introducers to the farmers before ICRAF established field trials with farmers. Also some extension workers provided training for farmers before projects from Dishutbun entered the village of Pana.

In West Kalimantan farmers tended to learn from their neighbours' experience because it was free. Individual farmers can learn by observing other farmers who successfully established clonal rubber plantations and they used these examples as evidence to follow. Some farmers in the decision making process might only base their information and observations on their neighbouring farmers. The farmers in West Kalimantan usually followed or copied other farmers, as they observed the result was good. One of the respondents mentioned:

> I do not want my grandson to ask me in the future why I did not plant clonal rubber when my neighbours planted it. I will be ashamed and I will be feeling guilty if I did not cultivate it like other farmers. So I planted clonal rubber and I hope the result will be as good as predicted (Adopters, Pana).

This result is the same with the case of the establishment of cocoa in Indonesia (Pomp and Burger, 1995). Potter and Lee (1998) argued that smallholders' access to land and their communications with other farmers informing them of the change in the value of tree crops have influence on their willingness to adopt new practises. Neighbour farmers helped the other farmers to increase their knowledge of new technologies especially in the case when lack of technical knowledge is a significant barrier to the adoption (Foster and Rosenzweig, 1995). Neighbours were an important source of information in both locations. This confirms that informal social networks such as relatives, friends and groups are an important possibility for spreading new technologies (Kiptot et al., 2006) and promoting "farmer-to-farmer" approaches (Chambers et al., 1989).

However, neighbours as a main source of information could also have a negative effect. This situation happened in some cases in Jambi, when the farmers referred to the unsuccessful neighbours who developed clonal rubber. The farmers became discouraged and did not want to take a risk to adopt clonal rubber. If these neighbours were not involved in the program, had no knowledge of clonal rubber or had bad experience planting clonal rubber, they had different levels of understanding about clonal rubber. These different sources have different degrees of credibility and perceived influence (Garforth and Norrish, 2000).

The other source of information is the village leader. Generally all village leaders have early access to information on new technology that comes to the village, as formerly all the projects had to be approved by the village leader. However the role can be different in each village as each has its own characteristics and policy. For example, the leader of the village has an important role as in the case of Embaong village. The head of the village of Embaong was mentioned in their interview by farmers who knew him as a good leader. One of his strong roles was his work in encouraging farmers in Embaong to change their local rubber to the proposed clonal rubber project in his village for better results, and almost all villagers had supported this. He proposed a credit system from a Credit Union, a private finance company, to support the development of clonal rubber for the villagers.

However in other villages in Jambi, as mentioned by respondents, there were constraints in the development of clonal rubber as the leader wished to keep the information for the people around him. This was what happened in the case study in Rantau Pandan, Jambi. Some respondents mentioned that information about clonal rubber as well as incentives were only spread to the relatives and people who were close to the village leader. Here implementing the project had limitations in that it could only be offered to a small number of farmers and poor farmers who feel they do not get enough attention from their village leader become jealous.

3. *Demonstration plots*

Based on the interview in the first fieldtrip with the adopters in both locations, establishing demonstration plots and visiting demonstration plots have important roles in increasing their confidence and enhancing their belief in clonal rubber. The ICRAF established demonstration plots of clonal rubber in the villages of Bungo district, Jambi and Sanggau district, West Kalimantan. The number of plots In Jambi and West Kalimantan can be seen in Table 7.2.

Table 7.2 ICRAF's Clonal rubber demonstration plots in Jambi and West Kalimantan

Jambi	Number of plots	Total Size plot (Ha)	West Kalimantan	Number of plots	Total Size plot (Ha)
Rantau Pandan	9	4.5	Embaong	10	5.6
Lubuk Kayu Aro	1	1	Pana	10	5
Sepunggur	9	4.5	Kopar	10	6.4
Pulau Temiang	3	1.5	Senunuk	5	2.5
Total	22		Total	35	

Source: (ICRAF, 2005)

The number of farmers who visited and observed demonstration plots differed between provinces. There were more farmers in West Kalimantan who observed demonstration plots than in Jambi (Figure 7.10).

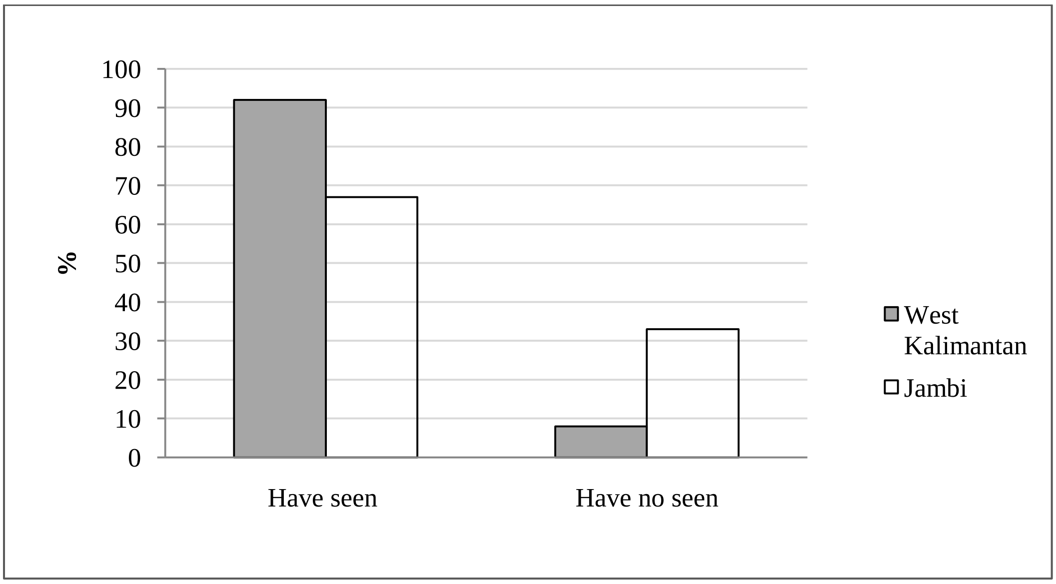


Figure 7.7 Farmers' experiences of seeing demonstration plots of clonal rubber

There were more demonstrations in West Kalimantan than Jambi. Most demonstration plots provided by ICRAF in Pana, Embaong, Kopar and Senunuk villages of West Kalimantan generally showed good results from the application of clonal rubber. In addition, demonstration plots in West Kalimantan were easy to recognise and observe by the other farmers. Some rubber farmers were interested in trying clonal rubber after they had seen the growth and the results of the early adopters. Some of the farmers also have experience of having seen other villages' clonal rubber, such as the farmers in Senunuk village who have seen clonal rubber from a neighbouring village called Sanjan. This village introduced clonal rubber in 1982-83, and in this village clonal rubber gave villagers more latex yield than the local rubber. Earlier information to the farmers may also increase their motivation to adopt clonal rubber.

In the case of Jambi, some farmers have not seen demonstration plots for several reasons, such as they said they have not received information about locations of demonstration plots as these were developed by individual farmers and in some villages there were less demonstration plots. Some of the farmers thought that demonstration plots were only for rich and educated farmers.

In some villages in Jambi, such as Sepunggur and Rantau Pandan some of the demonstration plots of clonal rubber failed to show better results, especially in their resistance to pest and diseases. These demonstration plots were unsuccessful because they were attacked by pest and diseases or destroyed by natural disasters (land slide and wind). Some demonstration plots were also slow in growth and had less production caused by mismanagement (less application of fertiliser, overexploitation etc). As individual farmers are involved in the demonstration plots, sometimes the researcher cannot fully control how the farmers manage their demonstration plots.

Understandably, demonstration plots are designed to be an important place for farmers to learn. However, in Jambi there was a lack of extension workers to explain what the farmers need to know and learn from the causes of unsuccessful demonstration plots. These demonstration plots were judged by the farmers as the failure of clonal rubber to be better alternative to local rubber. Some of the farmers had not seen a plot for themselves but they heard from other farmers who have an interpretation that the demonstration plot was not good enough to follow. As a result some of the farmers in this wide circle have a negative perception of clonal rubber as well.

Farmers' observation of demonstration plots has an important role in the decision process by increasing positive perception and their confidence prior to trialling new technology. The farmers can observe and evaluate the effectiveness of clonal rubber under land and environmental conditions similar to their own and this is important in the early stages of adoption (Rogers 2003). The positive perception of clonal rubber from observation of demonstration plots and other local examples of farmers' clonal rubber increased the adoption of clonal rubber. If they were satisfied with the result and they have enough capital and other support available, the farmers will continue to develop more clonal rubber (Oakley and Garforth, 1985; Pannell, 1997; Supriadi and Chamala, 1998). For example, adoption of farm forestry in rural India was due to the demonstration result of plots of progressive neighbour farmers (Glendinning et al., 2001). The farmers observe the practice from demonstration plots and these observations increase their belief in the profitability and other characteristics of new technology such as riskiness (Feder and O'Mara, 1982; Kiptot et al., 2006). Therefore, the more visible and the easier demonstration plots are to observe, and communicate about to farmers, the more chance technology will be adopted (Mwangi, 1998). In addition, social networks such as farmers groups mean that more farmers are aware of the plots and are given information which helps them interpret what they see. The farmers need to be confident that the technology will be successful over a long period (Pannell 1998) and to have plenty of time enquire before they try new technologies for themselves. For the researcher or extension worker, an on-farm trial can be used to study and to modify new technologies related to farmers' needs and availability of resources (Wibawa et al., 2005b).

The difference in the impact of demonstration plots in Jambi and West Kalimantan highlights the characteristics of successful plots. Success and the effectiveness of demonstration plots become important as poor quality demonstrations will affect farmers' perceptions of the technical reliability of the new technologies. A demonstration plot is an ideal way to show farmers a comparison between traditional and new practice, thus it can also help to build and increase farmer' confidence in a more scientific manner. Therefore, demonstration plots as well as practical techniques in the field may increase the positive attitude towards agroforestry technologies and have a positive influence on the adoption of new technologies (Oakley and Garforth, 1985; Sood and Mitchell, 2004). According to Rogers (2003) before adopting an innovation, some farmers carry out some small scale trial activities. Therefore demonstration plots were important and can be an effective strategy, especially in the early stages if they can be easily observed by farmers.

7.2.4 Social structure

1. Farmers' groups

Joining a farmers' group was one of the criteria for successful adoption of clonal rubber, especially for farmers in West Kalimantan. This is because the farmers' group has an important role in information exchange among farmers, for farmers with researchers and farmers with government and extension workers. The farmers group also has a function in organising and providing labour to establish a clonal rubber plantation.

The informal and formal relationships of farmers influence the farmers' groups that have been established in the farmers' community. As can be seen in Figure 7.11, there are around 65% of respondents in West Kalimantan who were members of farmers' groups and only 18% in Jambi.

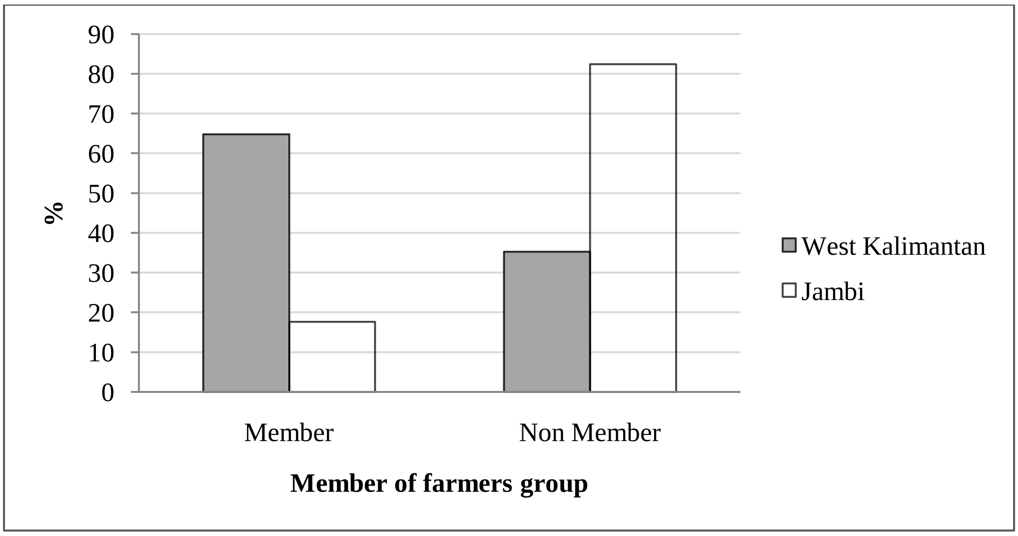


Figure 7.8 Members of Farmers' Groups

Farmers' groups in Pana village in West Kalimantan played an important role in the establishment and management of clonal rubber. There was one farmers' group in the beginning and its members were participants in the ICRAF project. In the beginning of the diffusion of clonal rubber, all members worked together to establish a demonstration plot on each member's land. During establishment each member learnt the technical knowledge of establishing clonal rubber starting from providing seedlings, nurseries, planting, weeding, fertilising and tapping. Each member was encouraged to join with other new farmers' groups to share their technical knowledge. This process was continued and spread the information to other farmers. These characteristics were likely to have a role in enhancing and driving the adoption of clonal rubber in West Kalimantan.

As mentioned in the previous Chapter 4 point 4.2.4 and this chapter part 7.2.2, *pengarih* is the traditional collective action of farmers in their agricultural activities that has been established for a long time, such as working together in preparing land for planting with paddy rice. When the clonal rubber project developed in the village, the farmers used this pengarih to work in rubber activities. The farmers altered their informal traditional farmers' group to semi formal. The informal groups have no formal organisation, but consist of farmers working together based on their traditional and cultural system.

Meanwhile, only 17% of farmers in Jambi have experience as a member of a farmers' group. As discussed in part 4.2.2, the role of traditional farmers' groups in this location was mostly working in agricultural activities. Since rubber management is based on individuals, there was no traditional farmers group for rubber. Farmers groups mostly were formal, based on the project and created as ordered by government to help project administration system such as in distribution of seedlings fertilisers and pesticides to farmers and also for evaluation of the project. These farmers groups were formed mainly for facilitating a connection between the Government and farmers in exchanging information between government officers and farmers, to simplify administration, deliver information and/or deliver incentives. This type of farmers' group usually only exists in terms of project activities.

During the project, usually the members have meetings regularly for preparation and implementation of the project. However, after delivery of the project then the farmers' group usually breaks up and becomes non-active. This was also because of internal conflicts among farmer group members after leaving the project. Some possible reasons for this were that the formation of the farmers' group did not come from, or was not initiated by the farmers themselves, but rather the farmers perceive that it was just needed for the project. Another reason was that extension workers rarely or never visit and do not have regular meetings with the farmers.

7.2.5 Policies and Institutions

Some of the farmers' decision criteria in the decision tree in Jambi and West Kalimantan may be influenced or linked to the government's policy. This section presents relevant policy background, based on interviews with the farmers, extension workers and government officers. The variables that are incorporated in this adoption study include access to credit or cash, access to infrastructure especially clonal seedlings and the role of NGO and government projects in the adoption of clonal rubber in Jambi and West Kalimantan.

1. *Incentives and credits*

In both West Kalimantan and Jambi, the criterion of incentive has important roles in the adoption of clonal rubber. This is mainly because the establishment of a clonal rubber plantation requires more cost, labour and inputs. Farmers mentioned that getting incentives was one of the main criteria for their adoption of clonal rubber. Without incentives, the farmers who have limited capital or have no other sources of income, find it difficult to adopt clonal rubber. Incentives can be production inputs like clonal seedlings, fertiliser, pesticides, and herbicides or a training program.

The farmers in Jambi and West Kalimantan received incentives for development of clonal rubber from various projects from government (Directorate of Crop Plantation), and international or national NGOs. The numbers of farmers who have got incentives were different between locations. Figure 7.12 shows percentages of farmer respondents who received and did not receive incentives.

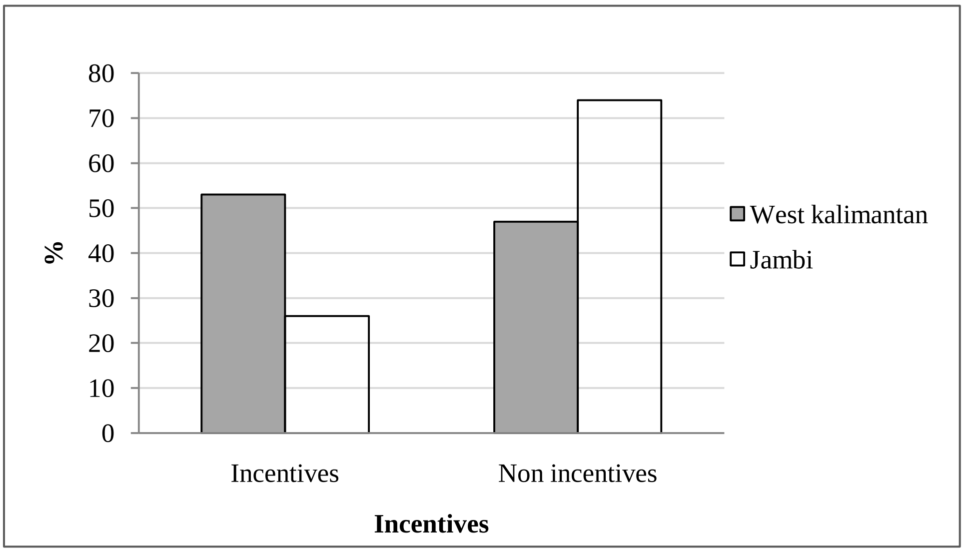


Figure 7.9 Percentage of farmer respondents who received incentives

The graph shows that more of the farmers in West Kalimantan have got incentives, especially free clonal seedlings, compared to Jambi. The government provided incentives in the project of rehabilitation of unproductive local rubber. The government of Sanggau supported the ICRAF program by delivering free clonal seedlings and other inputs to the farmers. The government did not need to offer training as the farmers' group facilitated the activities of learning among farmers.

In West Kalimantan, the farmers have alternative sources of credit such as Credit Union (CU)[3]. The role of the CU was important as this system supported farmers' economic activities (Kusmiran, 2007; PancurKasih, 2010; Petebang, 2009), including improving rubber productivity by the application of clonal rubber. The farmers in West Kalimantan especially in the village of Pana, Kopar and Embaong mentioned that their need for cash to start clonal rubber plantation or other business has been

[3] Credit Union is one form of cooperation that exists in Indonesia, especially in Kalimantan. CU is defined as a business unit owned by a group of people who join and trust each other, who agree to deposit their money so as to lend capital among themselves, with a decent interest, for productive purposes. The CU's philosophy is to help members through cooperation, solidarity, trust, and learning, so they can be independent. This system developed rapidly in Kalimantan and also other provinces as capital is a major constraint for the community to develop rubber and as the current credit system such as banks were known to favour large-scale enterprises only. The CU has become a popular economic movement that is also capable of assisting the farmers and community to be able to live. In the villages, especially in West Kalimantan, banks are losing ground to credit unions since most people preferred credit unions because they served people first rather than profit, there was no hassle in administration and they provided training for members. There were 10 large credit unions in West Kalimantan with members spread across Kalimantan, including Sanggau district.

supported by CU. Therefore they did not depend on the credit from Bank or government programs to start planting intensive clonal rubber.

Meanwhile in Jambi most of the farmers still depend on the incentives from credit delivered by government. At the time this research was carried out, Government staffs, in this case Directorate of Crop Plantation, have been delivering incentives and a credit program for farmers. However, from the interviews it was recognised that the farmers have difficulties applying for credit as they have no land certificate. Most of the farmers used the traditional system for evidence of ownership through use of the land.

In the current situation, in which land becomes scarcer, a certificate is important in rubber planting such as for application of credit from the bank. However, land certificates for the farmers mean a long process of administration and require high costs. Without the land certificate it is difficult to get credit. In addition, the respondents in Sepunggur and Pulau Temiang village mentioned they were worried that the government credit system usually took more time and needed complicated administration. This may delay supplying materials, such as cash for land clearing, seedlings, fertiliser and pesticides. The farmers were concerned that with the seasons they cannot wait for credit as they do not want to take the risk of planting clonal rubber out of season. Because they thought establishing clonal rubber was risky and if they failed, they could not pay back the credit and would also lose their land, they preferred to choose local rubber which they already know how to manage and require fewer inputs and less labour. The failure of many improved tree planting activities has resulted in smallholders being unable to repay their credit advances (Barlow and Tomich, 1991; Potter and Lee, 1998). This study found the case in Pulau Temiang village that many farmers in the past did not pay credit regularly which resulted in the government cancelling their land's certificate. Therefore, the integration of incentives or credit with other support such as intensive extension services and easy access to planting materials was very important to assist the success of the credit system (Potter and Lee, 1998).

As mentioned in the literature review, incentives and credits have both positive and negative aspects. Initial incentives or credit early in the diffusion process will enhance adoption and will thus facilitate further adoption and also reduce the risk of adoption (Alavalapati et al., 1995; Feder et al., 1985; McDonald and Brown, 2000; Rogers, 2003) . The study in Malaysia also indicated that smallholders were keen to adopt new technologies only when the relevant inputs were subsidized (Sail and Muhamad, 1994). However, by receiving incentives and credit, there is a possibility that the quality of adoption is low (Rogers, 2003). For example in the villages of Rantau Pandan and Sepunggur some of the farmers received clonal rubber because they were interested in getting incentives and access to the project facilities. However they did not plant the clonal rubber that was delivered by the Government project. The reasons were varied, but mostly because they were not sure of the quality of seedlings, did not know how to manage clonal rubber and lack of assistance from extension workers. This study did not find this situation in West Kalimantan.

2. *Access to clonal seedling*

The facilities for production of the main inputs for planting clonal rubber such as high quality clonal seedlings, fertilisers, and pesticides were important in adoption of clonal rubber. Lack of inputs for production or difficulty obtaining them at the farmers' level became one of the reasons for less adoption of rubber technologies by smallholder farmers in both locations. In Jambi it was found that only two farmers (one farmer in Rantau Pandan and one in Lubuk Kayu Aro village) built their own nurseries and produced limited numbers of seedlings for themselves. Most of the farmers still depend on incentives from the government project or farmers who have capital were looking for clonal seedlings from the private nurseries. However the number of private nurseries was limited. This was mentioned by one of the government extension workers in Bungo Jambi regarding lack of availability of clonal seedlings:

> I think farmers in Bungo find it difficult to adopt clonal rubber because clonal rubber is too expensive and farmers cannot afford the price of clonal, and limited nurseries provide clonal rubber, the farmers find it easier to get unselected seedlings from their or other old rubber gardens. The other reason is the farmers thought that clonal rubber is difficult to transport to the field (Extension worker, Jambi).

In this study I visited three private nurseries that were available in the Bungo and Tebo area, Jambi. These nurseries have been assisted by ICRAF for quality assessment of clonal seedlings. However these nurseries usually provide clonal seedlings for large capacity projects and get fewer orders from individual farmers and the price is still unaffordable for the farmers. Meanwhile, in traditional markets, in Rantau Pandan for example, local rubber seedlings were more available, cheaper and easier to get than clonal rubber. This condition affected the adoption of clonal rubber in Jambi more than West Kalimantan.

Availability and access to clonal seedlings in West Kalimantan was better compared to Jambi. Participant farmers in West Kalimantan have learned how to produce clonal rubber planting material from training that has been held by ICRAF or Dishutbun and some of them have become producers of clonal rubber seedlings. They have established nurseries in the village to increase the availability of improved clonal rubber and to reduce the price and the cost for transportation for the local farmers who want to change to clonal rubber. The price is sometimes negotiable and the system of trade is based on their friendship or family system. This helps other farmers to get planting materials easily.

I found in Pana village there were 10 farmers who actively developed their own nurseries to fulfil their own needs and also to sell to other farmers. In other villages such as Senunuk village seven farmers including one extension worker and in Kopar two farmers with nurseries were found. Some of them were young farmers who had a sense of business, teachers, leaders of farmers' groups or they had experience in working in private companies. These farmers often became sources for information on and development of clonal rubber in their villages.

Other nurseries were available in Sintang District, close to Sanggau District in West Kalimantan. Rubber farmers in this district were popular as producers of clonal rubber seedlings and they spread the seedlings to other districts. For this study one of the transmigrants from Java in the Sintang district who produced clonal rubber by employing farmers who have been trained by ICRAF was found and interviewed. He and his marketing team sell seedlings to farmers in Sintang and Sanggau districts by using motorcycles and come directly to the rubber farmers in the villages. They also sell in the local market during the planting season, usually September-January. This attractive system increases the access of rubber farmers to clonal rubber. In this case most of the nurseries and traders of clonal rubber were dominated by Javanese in the transmigration area in Sintang.

3. *The role of NGOs*

The importance of field assistance was also mentioned as one of the criteria in the decision tree in West Kalimantan. The farmers were convinced by extension workers and field assistants who helped introduce and establish demonstration plots of clonal rubber with intensive assistance in the field. For example farmers who did not believe that clonal rubber may grow in the infertile soil believed and utilised that land for growing clonal rubber.

The roles of field assistants, field researcher and extension workers in the field are important in encouraging farmers to adopt clonal rubber. The Indonesian Government, in this case the Dishutbun (DFECS) has the main responsibility to increase the rubber productivity of the smallholder rubber farmer. As discussed in chapter 2, historically the Government started to introduce clonal rubber in 1970. Policies, programs and projects have been introduced to rubber farmers, through national cooperation and under international agencies' assistance. However, many of the government projects have been less than successful, as they have limited budgets and lack of technical expertise (Potter and Lee, 1998).

The programs of the Dishutbun were mostly the introduction of clonal rubber in a monocultural system which was more intensive and concerned with increasing the productivity of rubber. Introduction of monoculture including rubber and oil palm monoculture however has potentially changed the traditional ways that have been established for generations. Monocultural rubber and oil palm plantation by large private estates provided opportunities for villagers to have a job as day labourers or as officer in the private estate. Many younger villagers are eager to work in the town or in the oil palm estates with monthly salary rather than doing tapping in their rubber garden. Young people graduated from high school have no job as officers but they did not want to work as labourers (Potter and Lee, 1998). In addition payment for paid labour in rubber work in Kopar village increased slightly as it has to compete for labourers who are more interested in working in the estate.

Two respondents in Kopar Village, West Kalimantan reported that since monocultural oil palm plantation had been established surrounding their village, the population of rats in their rice fields had increased. As a result yield of their paddy rice reduced. The farmers noticed cultivation of paddy rice was uneconomic, but they continue to cultivate it because it is important to produce *tuak* (traditional liquor) as part of their culture. This condition was also mentioned by Potter (2004).

When the second field research was conducted (February to April 2009), the price of rubber had fallen due to the so-called world rubber crisis. The period was a difficult one for farmers, as prices for palm oil and rubber were both low, while the costs of purchased foodstuffs and agricultural inputs such as fertiliser were high. Some farmers were not tapping rubber trees to produce latex as they were waiting for a better price. They thought with the low price of rubber it was not worthwhile tapping all day for a small amount of money. Most of the old farmers have an experience with the fluctuation of rubber price and they did not want to change their rubber plantation with other crops. They turned temporarily to other activities to get income such as traditional gold mining in the river, planting agricultural crops in the row of rubber trees and fishing. Meanwhile in West Kalimantan the rubber farmers who have oil palm plantation may still have alternative additional income. Some of the farmers cancelled the establishment of new rubber plantation, some of them started to plant oil palm plantation.

The monoculture system was difficult to apply for smallholder farmers because of the high requirement of capital and labour. Meanwhile, rubber agroforestry is believed to require less capital, cash for daily expenses and labour compared to the monocultural rubber system and also it provided other benefits (Wulan et al., 2001). However, jungle rubber or agroforestry rubber produces less compared to intensive monocultural rubber. Application of clonal rubber in an agroforestry system to increase yield is a compromise system. Rubber cultivation is a part of the local way of life because rubber cultivation is important for their economy and culture (Feintrenie and Levang, 2009) . In addition, a lot of famers still depend on other products from the jungle rubber. A benefit from rubber agroforest is that it conserves fruit trees and other useful species such as food, fuel wood and medicines (Michon et al, 1986). Some farmers have intercropped their clonal rubber with mixed fruit trees in the traditional style, even using pineapples as a cover crop, although such mixtures were forbidden by the original project (Potter, 2004) .

ICRAF with other institutions and NGOs launched the SRAP project which has emphasised improving the productivity of rubber in order to increase rubber farmers' livelihood and income. This project also adopts the benefits of the traditional system and conserving the environment by conserving trees and the forest system. This project was developed based on the assumption that the traditional system with its environmental function beside production is more suited to the local farmers who depend for their livelihood on the forest or jungle rubber. Also it was intended to solve the problem that local farmers have limited funds and labour.

In Sanggau District, the rubber agroforestry system model has been acknowledged by local government as an alternative to the rubber monoculture system. For example, in the program for application of clonal rubber, ICRAF provided training for farmers, demonstration plots and delivered incentives to a small number of farmers. Some of the farmers with training in the technical knowledge of clonal rubber from ICRAF had no incentives to start clonal rubber. Some of these adopters only had training in seedling preparation and some techniques of rubber maintenance and field trips to other locations of clonal rubber, but they have no other incentives such as seedlings, fertilisers or chemical herbicides and insecticides. To increase or to develop more areas of clonal rubber, the local government did not need to offer training for farmers, but just incentives and extension. This cooperation has an important role in developing areas of clonal rubber to improve the production and income of smallholder farmers. ICRAF and local government also support farmers' groups to produce clonal rubber seedlings to supply the government project. As a result, the project becomes from farmer to farmer. The other advantage was that the farmers themselves can guarantee the quality of clonal seedlings.

The situation was different in Jambi. In some cases the farmers feel confused with the different concepts of monocultural rubber that was introduced by government and rubber agroforestry from ICRAF, especially when the government agencies were introducing monocultural systems. Another problem was coordination in training and utilising demonstration plots. The limitations in the field assistance of ICRAF and extension workers of Dishutbun in the field may affect the dissemination of clonal rubber to the farmers.

The following interview with the field coordinator of the ICRAF project shows these differences:

> In Jambi the approach to the introduction of clonal rubber was more individual as they are more individualistic in the establishment of clonal rubber. We tried to have regular monitoring as we have to gather data from the field, but intensive assistance was difficult as we have limited field assistants and time. Ideally we would have coordination and working together with Dishutbun as we know that ICRAF will assist the farmers here based on the temporary project and we hope that Dishutbun can continue the program as they have the responsibility to cater for the rubber farmers here. For example, we work together with an extension worker in this area, who is also involved in our program. But again this is not working properly as we have limited numbers. On the other hand, farmers always need assistance and they are always waiting for us to start or do part of the project. Without controlling and monitoring, even though we have had an agreement that farmers have to follow the protocol, still they sometimes do not follow the protocol. As a result some demonstration plots have problems (Field manager, ICRAF, Jambi).

From this point of view, field assistance coordination with the Dishutbun technically in the field was not well established yet. This is probably because of lack of field staff and extension workers compared to the large area of smallholdings that have to be covered.

The function of extension workers for rubber plantation also needs to be improved. Information below is mentioned by one of extension workers in Bungo, Jambi:

> I did extension work based on the individual approach and did not do mass communication or meetings. Meetings are difficult to do, especially getting the right time to get farmers together as sometimes not many farmers attend the meeting. My main job now is how to motivate farmers to maintain their rubber to increase their productivity as long as I can as well as assisting if there is a project of introducing clonal rubber to help farmers. I have difficulties spreading information effectively as only myself has to cover all rubber farmers in two or three villages (Extension worker, Jambi).

The problems with extension workers are usually related to availability, the ratio of extension worker to farmers, less meetings and lack of communication. The extension workers in the field should be available from the start when they introduce the project until the end of the project. More frequent contact individually or in the group with the farmers is also essential for improving the effectiveness of the extension services (Sarker and Itohara, 2009).

The indication on the impact of extension services on farmers' adoption of new technology is generally positive (Mwangi, 1998; Sarkar, 1998; Suyamto et al., 2006). The role of extension workers is important in increasing the level of adoption of new technology at the farmers' level (Cramb, 2000). For example in the study of adoption of a timber based system in Sumatra, Indonesia, adoption of this practice was increased significantly when extension workers were able to convince farmers by reducing their perception of the risks (Suyamto et al., 2006).

The decision tree for West Kalimantan shows that farmers were persuaded by field assistants and this study also shows the close relationships between farmers and field assistants in Pana and Kopar village. This is similar to one of the principles of successful extension proposed (Chambers et al., 1989) and also Mwangi (1998) that in technology transfer the most important factor is the quality of interaction between farmers, extension workers and researchers based on mutual respect.

The quality of their information is also important. Field assistants with knowledge about clonal rubber have an important role in spreading accurate information to farmers. Access to information is very important in the adoption of new technologies. As the extension agent is the best source of information and training for farmers' participatory development, their credibility is very important for effective extension services (Mwangi, 1998). The accuracy and appropriateness of information may have an effect on the level of adoption by reducing farmers' aversion to the risks and uncertainty of new technology.

7.3 Decision Tree Model and Decision Making

This research emphasizes understanding what people do with the introduction of new technology and why they do it, what factors determine their decision to adopt or not adopt the technologies and how they make the decision. The Ethnographic Decision Tree Model enables a detailed examination of all the factors that affect a farmer's decision making. It not only lists the factors, but the factors can also be put together in relation to each other to understand decision making as a process. By using EDTM, the model identifies not only economic factors, but also identifies the social factors that are also important in farmers' decision making. The summary of the factors influencing decision making in adoption of clonal rubber is shown in Table 7.3.

This decision tree model in this study identified that smallholder rubber farmers in Jambi and West Kalimantan use a combination of different criteria or factors in the decision making process to adopt or not adopt clonal rubber. The analyses showed that economic, managerial, technical, socio cultural, and policy institutional aspects influenced the structure of the rubber farmers' decision making process to adopt or not adopt clonal rubber. The decision criteria show themselves to be interconnected and the combination of the criteria could result in different decisions of adoption by people who superficially appear to be facing similar circumstances.

The decision tree models show that in general the farmers both in Jambi and West Kalimantan have some similarities in the decision criteria that they use in order to adopt clonal rubber. The similarities are in the availability of land, the belief that they are getting a better yield from clonal, that replacing local seedlings with clonal rubber will raise their profit. They also have some similar factors determining in their adoption such as incentives, the role of demonstration plots, technical expertise, and the availability of clonal seedlings, knowledge and labour.

Table 7.3 Summary of the decision criteria of West Kalimantan and Jambi

	Categorisation		Factors from decision criteria	Jambi	West Kalimantan
1	Economic criteria	1	Availability Land	The land is relatively more available, still a chance for extension of holdings	Land is relatively more limited, expansion of oil palm plantation
		2	Expected Profit Increase	Main income, Yield accepted, but still need to be convinced	Main income, Yield accepted, more convinced
		3	Capital (cash)	Lack of capital	Lack of capital
		4	Risks and uncertainty	whether local rubber lives longer than clonal rubber, vertebrate pests, fungi	White root fungi; but less attacked than in Jambi, no vertebrate pests
2	Managerial criteria	5	Labour	Family labour, hired labour	Family labour, hired labour, collective labour
3	Technical criteria	6	Technical knowledge Training & Extension	Positive & negative In perceptions of rubber farmers it's too complicated farmers need time to change, need more training	Positive, farmers become more motivated as they have seen better results
		7	Information Exchange	Neighbours, family	Researchers, neighbours
		8	Demonstration plot	Some demonstrations failed	Most demonstrations showed the advantage of clonal rubber.
4	Social structure	9	Farmers group	No ongoing farmers' groups , Less transfer of knowledge farmers to farmers	Farmers' group in rubber , more transfer of knowledge farmer to farmer
5	Policy & Institution	10	Incentives and access to credit	Government, ICRAF, No alternative credit system	Government, ICRAF , Alternative Credit system
		11	Access to clonal seedling	Too expensive, difficult to get	More access to clonal rubber, producers, reasonable price
		12	relationship Government and NGO's	Need to be increased	More conducive

In the decision making process in the households, most of the respondents in Jambi and also West Kalimantan said they make decisions together. This is common as an agricultural system is a complex activity involving a lot of people in the operation of farm and household (Vanclay, 2002) including women. Rubber agroforestry is particularly complex. From the interviews it was found that men discussed these with women before making decisions regarding their rubber land. However, usually men are more dominant than women in decision making. For the final decision was mostly in the hands of the men, especially in making important decisions in their rubber farming, for jobs involving heavy work, or large amounts of money. Women in Jambi still face inequalities and have a weak position in controlling, accessing and influencing decision-making processes in their house and village level (Siagian et al., 2005).

In reality, in Bungo and Sanggau, even though women were more responsible for household activities and their children's education, women also have played an important role in rubber management. In Bungo, land inheritance tradition is matrilineal, land tends to be inherited through the female line, while rubber gardens are in a transition as lands are inherited through either male or female lines (Suyanto and Otsuka 2001, Suyanto et al. 2001). The role of women is also important in all the processes of establishment of rubber gardens. Women have an important role from the beginning of land clearing until rubber planting such as preparing food and helping removing debris. In harvesting, women do better on tapping of clonal rubber than on traditional rubber for several reasons. For example, women can more conveniently tap clonal rubber because usually the locations of clonal rubber are closer to their village therefore they still can do household work. Tapping clonal rubber also is easier for women as clonal rubber is planted at regular distances as in plantations rather than in jungle rubber that is similar in condition to forest. Also, women are preferred as tapping clonal has to be more careful due to its sensitivity to hard or careless tapping. Therefore women' role in the management of clonal rubber is important and will increase in the future.

Both places were conducive to developing rubber biophysically, historically and culturally. However, they have different conditions and constraints in regard to adopt clonal rubber. These different factors and conditions are leading to different levels of adoption of clonal rubber between Jambi and West Kalimantan. This study demonstrates the importance of local knowledge in deciding what will influence farmers' decision-making regarding the adoption of clonal rubber. The factors influencing farmers' adoption of clonal rubber are important in planning similar projects in accelerating the level of adoption.

7.4 Summary

Generally, the analyses of decision tree models for Jambi and West Kalimantan showed that economic, managerial, technical, socio-cultural, and policy institutional aspects influenced the structure of the rubber farmers' decision making process to adopt or not adopt clonal rubber.

In the economic aspect; as rubber was the main source of income, farmers' expectation of better yield became the main motivation for farmers to adopt clonal rubber. Because farmers want to make money, we should show them how a new technology will benefit them financially. Meanwhile limitation of capital and farmers' perception of risk and uncertainty mainly caused by pests and disease were the main constraints for non adopters.

In the managerial aspect; the shortage of family labour and lack of capital to pay labour become constraints in the adoption of clonal rubber. The availability of labour such as farmers having more family members' labour makes it more likely that clonal rubber can be established and tends to increase the adoption of clonal rubber. The lack of labour availability leads rubber farmers to continue with local rubber as they know it is easy and has a low demand for labour. Meanwhile in West Kalimantan the farmers may use the alternative of collective labour for working in their rubber garden.

In the technical criteria; training, demonstration plots and extension became important in supporting adoption of clonal rubber. Success of training, followed by establishment of demonstration plots and continuing assistance by extension workers increased farmers' confidence to adopt clonal rubber. West Kalimantan farmers trusted positive prior demonstration plots compared to Jambi. It is important that demonstration plots have the capability to show benefits of clonal rubber compared to local rubber, and should be easy for the farmers to observe and to learn from. In addition, guidance and assistance from extension workers are needed in order to interpret the result of the application of clonal rubber in the demonstration plots. Further, the farmers will have more confidence in adopting clonal rubber after observation of the demonstration plots, technical information alone was not enough.

In policy and institutional aspect; West Kalimantan, compared to Jambi, seems to be more conducive to farmers adopting RAS technology – there is better availability of and access to planting materials, better access to incentives and credit, support from and trust in field staff and farmer networks.

In social aspect; In Jambi where people perceived that cultivation of rubber was more individualistic rather than working in the group, they have problems with labour in establishing clonal rubber. However, collective actions in the villages in Jambi were available in agricultural and other social activities. Meanwhile in West Kalimantan the farmers may use the alternative of collective labour for working in their rubber garden. The availability of labour for a clonal rubber plantation also depends on the family size that can be utilised in a clonal rubber garden and the availability of paid labour and collective labour.

Local leadership and relationships with village elites were also shown to influence spread of clonal rubber with some villages being more supportive of general wellbeing and some more individualistic.

In general the decision criteria approach showed that different farmers have different constraints and criteria therefore different approaches are required for technology diffusion. The criteria are also shown to be interconnected and, consequently, comprehensive integrated solutions are required to increase adoption of clonal rubber.

Chapter 8 Quantitative Analysis of Adoption of Clonal Rubber

8.1 Introduction

This chapter presents the quantitative model of the adoption of clonal rubber by the smallholder farmers in Jambi and West Kalimantan. This model is to complement the decision tree models. The first part of this chapter presents the descriptive statistical analysis of the characteristics of respondents. Then, the variables that influenced the adoption of clonal rubber from the decision tree are presented. Further, correlation analysis is used to examine the relationship between variables and to show whether and how strongly pairs of variables are related. Then a logistic regression model is applied to provide a useful means for modelling the variables. Discussion of variables and the contribution of the quantitative model to the decision tree are also elaborated in this chapter.

8.2 Result

8.2.1 Variables

The probability of the adoption of clonal rubber technology is modelled as a function of particular characteristics of rubber farmers. According to the literature, as discussed in detail in Chapter 3, the decision to adopt new technologies in agroforestry is determined by various factors including social, cultural and economic. Further characteristics such as, the age and education of heads of households, family labour available in households, experience as rubber farmers, land size ownership, and income of households also influenced the adoption of agroforestry technologies. Based on the survey and ethnographic interview for the development of decision tree models (see Chapter 4) factors found to be determinants for the adoption of clonal rubber are used as independent variables for the logistic model. The summary descriptive statistics for these independent variables incorporated in the empirical logit models are presented in Tables 8.1 and 8.2. The dependent variable for this logit model is a binary: it takes the value of 1 if the farmer adopted the clonal rubber and 0 otherwise. Table 8.1 shows the data of continuous variables.

Table 8.1 Data of the continuous variables of respondents in Jambi and West Kalimantan based on categorical adopters and non adopters

Variables	Category	Jambi			West Kalimantan		
		N	Mean	Std. Dev	N	Mean	Std.Dev
Age (Years)	Non Adopters	76	44.93	10.40	14	38.57	11.84
	Adopters	49	47.45	10.68	94	42.52	12.24
Education (Years)	Non Adopters	76	7.96	2.70	14	7.71	1.94
	Adopters	49	8.51	2.96	94	8.05	2.84
Labour	Non Adopters	76	2.38	.864	14	2.07	.92
	Adopters	49	2.49	.916	94	2.23	.74
Experience (Years)	Non Adopters	76	18.61	9.39	14	16.50	10.29
	Adopters	49	21.41	9.28	94	21.50	11.81
Land size (Hectares)	Non Adopters	76	5.5638	4.38	14	4.4143	2.72
	Adopters	49	6.6459	5.68	94	3.2553	1.84
Income (IDR)	Non Adopters	76	28.5774	21.61	14	18.4207	13.64
	Adopters	49	39.3306	34.35	94	27.6709	15.33

Table 8.2 Data of dichotomous variables of respondents based on categorical adopters and non adopters in Jambi and West Kalimantan

Factors		West Kalimantan			Jambi		
		Non Adopter	Adopter	Total	Non Adopter	Adopter	Total
		(%)	(%)	(%)	(%)	(%)	(%)
Incentives	No	12.0	33.3	45.4	58.4	16.0	74.4
	Yes	0.9	53.7	54.6	2.4	23.2	25.6
	Total	13.0	87.0	100.0	60.8	39.2	100.0
Off Farm Jobs	No	11.1	63.9	75.0	33.6	21.6	55.2
	Yes	1.9	23.1	25.0	27.2	17.6	44.8
	Total	13.0	87.0	100.0	60.8	39.2	0.0
Farmers' Group	No	5.6	34.3	39.8	51.2	31.2	82.4
	Yes	7.4	52.8	60.2	9.6	8.0	17.6
	Total	13.0	87.0	100.0	60.8	39.2	0.0
Demonstration Plots	No	3.7	9.3	13.0	28.8	4.0	32.8
	Yes	9.3	77.8	87.0	32.0	35.2	67.2
	Total	13.0	87.0	100.0	60.8	39.2	100.0
Training	No	8.3	43.5	51.9	54.4	23.2	77.6
	Yes	4.6	43.5	48.1	6.4	16.0	22.4
	Total	13.0	87.0	100.0	60.8	39.2	100.0

The survey data revealed that 87% of the total sample of farmers in West Kalimantan adopted clonal rubber practices. Meanwhile only about 39% of the sample farmers in Jambi were adopters.

In this study, a logistic regression model is used. It has been used in many studies of agroforestry adoption (Mercer, 2004). The SPSS (Statistical package for the Social Sciences) version 17.0 software (Coakes et al., 2009) is used to develop logistic models for each location; Jambi and West Kalimantan. The general model for logit is:

$$\ln\left[\frac{P_i(R_i = 1)}{1 - P_i(R_i = 1)}\right]$$
$$= \beta 0 + \beta_1(Age) + \beta_2(Educ) + \beta_3(farmLabour) + \beta_4(Exp) + \beta_5(Land) + \beta_6(Incentive) + \beta_7(Income) + \beta_8(OffFarmJob) + \beta_9(FarmGroup) + \beta_{10}(Demo) + \beta_{11}(Training)$$

Stepwise regression was used to choose model variables that were significant at the 1% level.

8.2.2 Logit Model Analysis in Jambi

A correlation matrix is used to show all possible correlation coefficients between a set of determinant variables. The analysis of the correlation matrix in Table 8.3 indicates that some of the variables have strong linear correlations with decisions. The Table shows that incentives, having experience in observing demonstrations and training have high correlation with farmers' decisions to adopt or not adopt clonal rubber. The income factor has a correlation with the decision but is less strong than the incentive variable. Training has high correlation with the decision, but also it has high correlation with incentives and off farm jobs. The results produced from the logit models for Jambi are given in Table 8.4.

Table 8.3 Correlation matrix of explanatory variables used in the clonal rubber adoption behavior models for farmers in Jambi (n = 125)

	Deci-sion	Age	Educ	Fam lab	Exp	Land size	Incen -tives	Off farm jobs	In-come	Farm group	Demo	Trai-ning
Decision	**1**											
Age	**.117**	**1**										
Education	**.096**	**-.208***	**1**									
Fam labour	**.06**	**.195***	**-.161**	**1**								
Experiences	**.146**	**.849****	**-.215***	**.17**	**1**							
Land size	**.107**	**.191***	**.008**	**.012**	**.202***	**1**						
Incentives	**.618****	**.113**	**.14**	**.092**	**.138**	**.194***	**1**					
Off farm jobs	**.002**	**.025**	**.242****	**-.123**	**.015**	**.199***	**.098**	**1**				
Income	**.190***	**.046**	**.324****	**.016**	**.041**	**.355****	**.024**	**.418****	**1**			
Farmer group	**.059**	**-.052**	**.091**	**.04**	**-.01**	**-.05**	**.066**	**-.16**	**-.084**	**1**		
Demos	**.386****	**.016**	**.05**	**-.01**	**.083**	**.04**	**.215***	**.081**	**.264****	**-.169**	**1**	
Training	**.355****	**.101**	**.206***	**.025**	**.123**	**.113**	**.564****	**.326****	**.092**	**.004**	**.171**	**1**

*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed).

Table 8.4 Final model logit regression estimates of coefficients associated with the factors affecting the decision of the adoption of clonal rubber by farmers in Jambi.

Variables	β	S.E.	Wald	Sig.	Exp(B)
Incentives	3.709**	0.745	24.781	0.0001	40.817
Demonstration plots	2.275**	0.706	10.375	0.001	9.725
Constant	-3.021***	0.680	19.716	0.0001	0.049
-2Log-Likelihood	102.87				
Chi-square, level of significance	*65.33 (P<0.0001)*				
Level of correct prediction	*82%*				

Based on the logit model, there are two variables from the eleven variables, namely incentives and demonstration plots that have a highly significant effect on the adoption of clonal rubber. Explanatory variables of incentives and demonstrations are both significant at the 1% level and have a positive sign. The log-likelihood which represents the difference between the current model and the model with a constant to test the null hypothesis that the coefficients for all of the variables in the model are zero is 102.87. The chi-square statistic for the model is 65.3, which is significant at 0.0001 levels for the log likelihood ratio of the model at 102.87 therefore the model fits the data well. The smaller the value is the better the fit. The present estimated logit model correctly predicted and classified 81.6% of the outcomes.

8.2.3 Logit Model Analysis in West Kalimantan

Table 8.5 shows the correlation matrix analysis of the potential explanatory variables determinant for the adoption of clonal rubber in West Kalimantan. The Table shows there are three variables that had a significant linear correlation with the decision to adopt clonal rubber namely land size, incentives and income.

Table 8.5 Correlation matrix of explanatory variables used in the clonal rubber adoption behavior models for farmers in West Kalimantan (n = 125)

	Deci-sion	Age	Educ	Fam lab	Exp	Land size	Incen-tives	Off farm jobs	In-come	Farm group	Demo	Trai-ning
Decision	**1**											
Age	**.109**	**1**										
Education	**.042**	**-.253****	**1**									
Fam labour	**.072**	**.390****	**-.207***	**1**								
Experiences	**.144**	**.885****	**-.240***	**.341****	**1**							
Land size	**-.196***	**.213***	**.099**	**.199***	**.177**	**1**						
Incentives	**.368****	**.258****	**.030**	**.207***	**.198***	**.021**	**1**					
Off farm jobs	**.095**	**-.094**	**.453****	**-.049**	**-.081**	**.125**	**.140**	**1**				
Income	**.203***	**.185**	**.113**	**-.044**	**.262****	**.288****	**-.009**	**.141**	**1**			
Farmer group	**.121**	**.257****	**-.045**	**.114**	**.233***	**.236***	**.550****	**.184**	**.111**	**1**		
Demos	**.039**	**.017**	**-.031**	**-.056**	**-.032**	**.099**	**.092**	**.204***	**.136**	**.000**	**1**	
Training	**.096**	**.208***	**-.126**	**.072**	**.191***	**.057**	**.283****	**.043**	**.084**	**.213***	**.046**	**1**

*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed).

Table 8.6 Final logit regression estimates of coefficients associated with the factors affecting the decision to adopt clonal rubber by farmers in West Kalimantan.

Variables	β	S.E.	Wald	Sig.	Exp(B)
Land	-0.449**	0.169	7.052	0.008	0.638
Incentives	3.453**	1.159	8.876	0.003	31.601
Income	0.081**	0.033	5.971	0.015	1.084
Constant	0.718	0.845	0.723	0.395	2.051
-2Log-likelihood	*52.96*				
Model chi-square Level of significance	*30.3 (P<0.0003)*				
Level of correct prediction	*89%*				

Table 8.6 shows that three variables namely land, incentives and income are shown to be main determinants of clonal rubber adoption in this area. These explanatory variables of land and incentives are both significant at the 1% level. A positive sign of incentive variables is as expected, but land has negative significance and is different from the expectation. The chi-square statistic for the model is

30.3 at p-value of 0.0003 and the level for the -2log likelihood ratio of the model is 52.96 showing that the model is different from zero and significant. The present estimated logit model correctly predicted and classified 89 % of the outcomes.

8.3 Discussion on Logit Models

Based on logit analysis there are two significant variables for predicting the adoption of clonal rubber by rubber farmers in Jambi. Other variables mentioned in Tables 8.1 and 8.2 were also tested, but not included in the final model as they were not significant, as those did not get selected when stepwise regression is used. The significant variables are incentives and demonstration plots. These variables are positively related to the adoption of clonal rubber in Jambi. The positive and significant sign of demonstration plots indicated that the probability of the adoption of clonal rubber is higher for farmers who had observed successful demonstration plots compared to those who have not seen them. This indicates farmers are influenced by exhibitions of demonstration plots in the adoption of clonal rubber. This also suggests that the more farmers observe and are involved in demonstration plots, the greater their chance of adopting clonal rubber because they acquire more knowledge or better informed and more confidence to adopt clonal rubber. This result is similar to the results of the study by Evans (1988) that demonstration plots improve the observability of agroforestry systems and have been shown to have a direct influence on agroforestry adoption rates.

Based on the logistic model in Table 8.6 only three predictors of farmers' decisions to adopt clonal rubber in West Kalimantan are significant. These variables are incentives, land and income. Incentives and income have positive sign, meanwhile land is negative. The positive and significant signs for income indicated the higher the level of income the more the likelihood of rubber farmers applying clonal rubber.

This suggests that the farmers with higher incomes will be more capable of buying clonal seedlings, fertiliser and pesticides, paying for labour and therefore more opportunity to adopt clonal rubber.

The significant negative coefficient for land size in the West Kalimantan model indicates that scarcity and decreased land size available or owned by farmers increased the possibilities of farmers adopting clonal rubber. This suggests that farmers with smaller parcels of land are more willing to adopt clonal rubber in order to increase the productivity of land.

8.4 Comparison of Jambi and West Kalimantan

The incentives variable is significant in both areas, Jambi and West Kalimantan. This result indicates that this variable has an important role for farmers in both areas to establish clonal rubber as they cannot pay their own costs the first time. The rubber farmers have limitations in capital and establishment of clonal rubber needs higher costs, therefore they depend on incentives from different sources mainly from government projects. This study indicates, incentives may increase the adoption of clonal rubber in Jambi and West Kalimantan. The role of incentives is discussed in Chapter 7 part 7.2.5.

Table 8.7 Logit regression estimates of coefficients associated with the factors affecting the decision to adopt clonal rubber by farmers in Jambi and West Kalimantan.

	Jambi			West Kalimantan		
Factors	β	Sig.	Exp(B)	β	Sig.	Exp(B)
Incentives	3.709***	0.0001	40.817	3.453**	0.003	31.601
Income	-	-	-	0.081**	0.015	1.084
Demonstration plots	2.275**	0.001	9.725	-	-	-
Land	-	-	-	-0.449**	0.008	0.638
Constant	-3.021***	0.0001	0.049	0.718	0.395	2.051
-2Log-likelihood	*102.87*			*52.96*		
Model chi-square (Level of significance)	*65.33 (P<0.0001)*			*30.3 (P<0.0003)*		
Level of correct prediction	*82%*			*89%*		

In the case of land variables, understandably, this could be due to most farmers' land in West Kalimantan having been decreased through many factors such as increased population, conversion of land to private oil palm plantation and transmigration.

This logit model result suggests a decreased land area increased their eagerness to adopt clonal rubber in order to increase productivity. Adoption and application of clonal rubber for higher yield on a small parcel of land was one of the alternatives to increase rubber yield and to increase their income from the limited area of land.

Meanwhile farmers in Jambi still have possibilities to extend their rubber area by clearing forest or old rubber jungle (see more discussion in Chapter 7 part 7.2.1).

8.5 The Decision Tree and Logit Models

This study shows that decision trees and the statistical logit model inform the factors and determinants of adoption of clonal rubber. The decision tree model found twelve main factors that are involved in the decision making process in the adoption of clonal rubber as shown in Figures 5.6 and 6.6. Meanwhile, the results of the empirical model of logit analysis presented in Table 8.4 and Table 8.6 indicate that four of the independent variables are significantly associated with the adoption of clonal rubber at the 1% level of significance. These factors are land, incentives, income, and demonstration plots. In this study these two models of the process of choosing show a similar percentage of prediction. The logit model predicts a high 82% for Jambi and 89% for West Kalimantan of both adopters and non adopters. The prediction is similar to the decision tree results which is 82% for Jambi and 83% for West Kalimantan.

In this study, the logit model can be used in complementary ways to decision tree models especially in highlighting significant factors involved. The result of the logit model confirmed and complemented the result of decision tree model. For example, the logit results show that the incentives variable, as predicted, is positively and significantly related to the farmers' adoption of clonal rubber in Jambi and West Kalimantan. This result indicates that clonal rubber is more likely adopted by farmers who had incentives. This finding is consistent with the important role of incentive criterion in the decision tree for both locations. The decision tree model for Jambi shows that 26 (43%) respondents chose clonal rubber because of the incentive criterion (criterion no 3) and 10 respondents decided not to adopt clonal rubber as they have no incentives and have insufficient capital. The decision tree model of

West Kalimantan shows 28 (58%) respondents in West Kalimantan also used this criterion as the reason to adopt clonal rubber. This logit result confirmed the significance and importance of the role of incentives for the farmers to start planting clonal rubber.

Another example was the importance of the land criterion (criterion no 1) in the decision tree, however this criterion did not tell in what direction land influenced the rubber farmer's decision. In the logit model, the negative sign of land variable in West Kalimantan indicates that scarcity and decreased land availability increased the possibilities of farmers adopting clonal rubber. This suggests that farmers with smaller parcels of land were more willing to adopt clonal rubber in order to increase the productivity of land. It was probably because the smallholder farmers were concerned how they could make their limited land more viable economically and could increase their income. This result also happened in the case study of the adoption of agriculture which used the logit approach in Cameroon (Gockowski and Ndoumbéb, 2004). Their study showed that increasing land constraints positively influence adoption as the farmers tried to increase agricultural production.

In this adoption study, the decision tree model identified all the decision criteria and constraints in the adoption of clonal rubber and the processes which were followed by farmers regarding their decision making. However the model does not give information on how significant the criterion was. In this model, based on Gladwin's theory (1989a), people processed all of the information they received and they made a decision based on criterion without ranking or quantifying the importance of the criterion. Quantification and significance is then determined using a quantitative model such as logit regression. It can be seen from this study that the decision trees contain all the criteria processed by individual farmers in a group, while logit regression analysis highlights those that were significant. This result is compatible with the findings in the study of Gladwin et al (2002a). They used logit and ordered probit analysis to test the result of decision tree in their study in adoption of improved agroforestry in Zambia. They conclude that "*regression results method confirmed ethnographic observations because regression analysis allows the researcher to hold constant all other significant variables"* (Gladwin et al., 2002a, pp.523). In addition, Mercer (2004) also agreed that the combination of the decision tree as a cognitive model with logistic regression as an econometric model can advance the study of adoption.

However, the logit analysis shows that only a few variables from decision trees were significant. None of the variables such as age, education, experience, family labour and farmers' group were significantly associated with the adoption of clonal rubber. This result was different to the prediction from the decision trees. For example based on decision tree models and also observations in the field, farmers' groups in West Kalimantan have an important role in the decision to adopt as they provide information, technical knowledge and labour. Meanwhile, the logit result shows that farmers' group was not a significant variable. Gladwin et.al (2002a) stated that it is normal that only a few decision factors to be significant in a regression analysis. This is because logit analysis cannot handle many independent variables otherwise it created too many distinct covariate patterns to perform the analysis (Fonow and Cook, 1991). However, as Gladwin et al (2002a) mentioned, the combination of two approaches is still valuable to use as the results of regression analysis provide complementary information. Even though based on logit models some variables were not significant, this did not necessarily indicate the nonexistence of these variables in the adoption process.

In this study, the logit model provides a statistical test of significance of variables that influence the adoption process and the qualitative methods explain descriptively all the factors including those not significant in the quantitative method. Therefore this study used and valued the result of the two approaches to highlight all factors.

Using a decision tree and logistic regression would help in designing proper approaches based on the key variables and also based on the process that farmers followed in the decision process. This will be beneficial for the government to develop policy, or for researchers, NGO and other related stakeholders to modify technology, and to adjust dissemination methods and other interventions needed to accelerate the rate of adoption. Additionally by using the logit approach which highlights particular factors that are significant, when there is limitation in time, staff and funds, then intervention can be focused on significant variables.

8.6 Summary

This chapter has attempted to determine the factors that affect farmers' decisions on the adoption of clonal rubber technologies using the logistic model. The logit analyses show that from twelve criteria in the decision tree model, four variables have a significant influence on the adoption of clonal rubber. In the adoption of clonal rubber in Jambi the factors of incentives and demonstration plots are significant and in West Kalimantan land, incentives and income are significant. Incentives are an indicator of the available economic resources to start clonal rubber in both locations and the willingness to adopt a new technology.

This study shows that a logit (quantitative) model complements the decision tree models by highlighting the significant factors in the adoption of clonal rubber in Jambi and West Kalimantan. The two different kinds of methods give different kinds of information to stakeholders and policy makers, and are both valuable.

Chapter 9 Conclusion and Recommendations

9.1 Introduction

This chapter concludes the thesis. It begins with a summary of the key findings of this study regarding decision making in the adoption of agroforestry technologies in Jambi and West Kalimantan. Inferences are drawn, and recommendations and suggestions relevant to the diffusion of agroforestry technologies are offered for government, researchers and other concerned parties. Further possibilities for improvement and suggestions for the advancement of agroforestry research in general, as well as extension and policy approaches in the dissemination of agroforestry technologies in Indonesia are proposed. Finally implications for further study related to decision making and adoption are presented.

9.2 Key Findings

1. *Importance of the study*

Indonesia has an important position as a rubber producer, possessing the largest rubber area and being the second biggest rubber producer in the world. The contribution of rubber to national, economic and social development has been and still is very important. However, smallholding rubber, the dominant rubber producer in Indonesia, has low productivity. The Indonesian government has, in collaboration with other related national and international agencies, introduced various schemes including dissemination of new technology programmes to increase rubber production and farmers' incomes. However adoption of improved technologies by smallholder rubber farmers remains low. By using case studies in Jambi and West Kalimantan an attempt was made to discover the reasons behind this lower adoption. This study was mainly intended to gain a deep insight into the rubber farmers' decision making and actual decision criteria in the adoption of clonal rubber into their agroforestry system and the factors influencing farmers' decision making. Therefore, the study may contribute to the Indonesian Government's or research agencies' intervention to accelerate the adoption of clonal rubber to increase production and incomes of smallholder rubber farmers.

2. *Methodology*

A case study approach was used to analyse the adoption of clonal rubber in Bungo District of Jambi province and in the Sanggau District of West Kalimantan. The main data collection methods were semi ethnographic interview for the development of the decision tree model and a structured interview for background, testing the decision tree and building a logit model. The data were analyzed using descriptive statistics, constructing decision trees and using logit regression. The combination of methodologies of data collection and analysis may answer the objective of the study and enrich the discussion.

The combination of a qualitative approach represented by the ethnographic decision tree model (Gladwin, 1989a) and a quantitative model (logistic regression) deals with the complications of the farmers' decision process in the adoption of clonal rubber. These approaches were used to examine the factors influencing the farmers' decision and to analyse the interrelationship between these factors, including farmers' information processing approaches, perceptions, socio-economic conditions, cultural and also policy influences. From my experience application of qualitative method is challenging. This process was new to me, as a forestry graduate I had training in quantitative methods rather than qualitative research techniques. As a qualitative social science research method, the approach to data collection for ETDM is unstructured and personal. I built up interaction with respondents to ensure natural conversation could take place with no detailed scenario set up when I began my first interviews. Use of the structured questionnaires followed the initial interview. Although I am Indonesian, the interviews did not take place in my home area and there were some cultural and language barriers to overcome. It took time and patience to get the information and the data are collected in raw format. The analysis of the data also took time as I had to derive interpretation and key points from respondents' descriptions and explanations. The process of interpreting and aggregating the results of individual interviews was complicated. The result is the crystallization of the data into limited and simplified decision criteria. However, this method provides depth information of decision types and processes that are followed by farmers as decision makers. In addition the EDTM method, unlike some other qualitative methods, allows the model to be established and then tested instantly, comparing the new results with the decision tree and confirming their accuracy. This is different to implementation of a quantitative model such as logistic regression. Structured questionnaires can be applied and data collection is relatively faster than with unstructured interviews. However, as the decision making process in adoption new technology is complicated, using a qualitative model beside quantitative or mathematical approaches was beneficial. A qualitative study as the first stage of quantitative study is useful to identify the significant variables as well as the decision making process involved (Murray-Prior and Wright, 2001).

3. Motivations and Constraints

The results of this study show that the process of adoption is complex and dynamic and the various factors are likely to influence and be interdependent with one another in the decision making process. From the decision tree model the farmers in Jambi and West Kalimantan used decision criteria related to the economic criteria (profit expectation, capital, land ownership, cash flow), risk and uncertainty, managerial criteria (labour and information), technical criteria (technology characteristics, farmers' knowledge, training and extension and demonstration plots), social structure (farmer groups, land system, communication channels) policy and institutions (incentives, credit, infrastructure).

The main constraint in adoption for both areas area was limitation of capital. Smallholder farmers are generally categorised as poor and have less income because they have a small sized land asset and limited other alternative income sources. With limited cash they have difficulties starting intensive clonal rubber. Inputs required establishing clonal rubber (such as clonal seedlings, fertilisers, labour and other related requirements) become too expensive to pay for. This is in line with the study of Levang and Sitorus (2006) and Penot (2004) who found that farmers in Sumatra do not use an intensive system generally because of constraints rather than choice.

The other constraint is risk and uncertainty. The farmers in Jambi faced risk and uncertainty caused by pests and disease which are considered environmentally and culturally unavoidable. This obstacle reduced the attractiveness of clonal rubber as the rubber farmers feared the risk involved in planting clonal rubber. This result is similar to other studies conducted by Williams et al. (2001), Levang and Sitorus (2006), Joshi et al. (2003) and Joshi et al. (2006).

The shortage of labour is also a constraint in the adoption of clonal rubber in both areas. Family labour, which is the main source of labour for rubber smallholdings, has been decreasing. Lack of labour is mostly caused by young families having under age children to care for and young people with higher education moving to the city or working in the oil palm or mining companies. Labourers become more difficult to find during the years of low prices of latex, in the season of harvesting paddy rice and the time for collecting oil palm. In West Kalimantan the farmers may use the alternative of collective labour and farmers' groups for working in their rubber garden. Meanwhile, farmers in Jambi are typically working individually in their rubber garden.

Social factors also have roles in farmers' decision making. This study identified socio cultural constraints that exist in Jambi. For example the farmers in Jambi believed by practising a traditional system with unselected seedlings from jungle rubber the resultant rubber has a longer life, and meanwhile clonal rubber was more easily attacked by fungi and pests. Some farmers were doubtful about the suitability of the new technology and also familiarity with the traditional practice from generation to generation was one of the reasons to continue planting local rubber.

4. *Differences between Jambi and West Kalimantan*

The analysis explored the structure of the farmers' decision making process in both Jambi and West Kalimantan, and there were some differences as some criteria in Jambi did not apply in West Kalimantan, and there were different conditions that farmers had to manage. For example wild pig was not present as pests for clonal rubber in West Kalimantan. Environment and culture in Sanggau West Kalimantan led to effective control of wild pig. The farmers of West Kalimantan have more alternative access to credit as a credit union system is available for farmers to improve farmers' economic activities. Their access to credit is greater compared to Jambi.

The logit models show that some of the important factors that have influenced farmers' decisions on adoption of clonal rubber elicited through in-depth interviews are supported by statistical analyses. In Jambi, the factor of demonstration plots was statistically significant and indicated that the probability of the adoption of clonal rubber was higher for farmers who had observed successful demonstration plots. The farmers who observed successful demonstration plots tended to follow and to imitate them in their own land. In the case of West Kalimantan land and income variables were also a significant factor. Understandably, this could be due to scarcity of land in West Kalimantan increasing their enthusiasm to adopt clonal rubber in order to increase land productivity. Effect of land scarcity that leads to adoption of an intensive system was also found in the study by Paudel (2002).

Based on factors affecting the adoption of clonal rubber and including policy and institutional aspects, West Kalimantan seems to be more conducive to farmers adopting clonal rubber than Jambi as it has better availability of and access to planting materials and more possibilities of access to incentives and credit.

5. The importance of information exchange

This study found that informal networks are important and one of the keys for successful adoption in West Kalimantan. The exchanges of information through informal networks and relationships between farmers are important to the analysis of social factors of the farmers as well as analysis of the farmers' perspectives regarding adoption of clonal rubber. The keys to spreading information and knowledge of new technologies in West Kalimantan are transformation, farmer to farmer relationships and social cohesion.

Transformation: An adaptation of traditional collective action is the formal farmers' group system which has structural organisation and better administration. This farmers' group system encouraged the farmers to work together to reduce constraints such as lack of information, technical knowledge and lack of labour.

Farmer to farmer: Each farmer has a responsibility to teach other farmers about clonal rubber plantation. Farmers who have no training may learn from other farmers. In their farmers' groups at least one member is a farmer who has formal training, so he/she can spread the information and knowledge to other members. There are several ways to gather information from others, including observing other farmers' behaviour and imitating it (Katungi, 2007). This process can be called social learning as one individual is learning from another by means of observational modelling (Rogers, 2003).

Strong cohesion between farmers: One of the keys to success in the establishment of clonal rubber in West Kalimantan is the farmers' strong relationships in the farmers' group. In Jambi most of the working together is for agricultural activities such as in paddy rice and is more popular among women, but the farmers work individually in clonal rubber.

6. Decision making process

The combination of the decision tree model and logit approaches dealing with the issues of the decision process in adopting or not adopting clonal rubber is complementary. The decision tree provides a better understanding of the farmers' behaviour, despite its simplicity in picturing the real world decision making process (Gladwin, 1989a). It also shows how farmers' strategies will change over time; adoption is not a single action. The decision tree has a description of rich information in detail and the logit model shows the factors that are statistically significant (Gladwin et al., 2002a). The decision tree models and logistic model show that different farmers have different criteria and constraints and therefore different approaches are required for technology dissemination.

This study shows that rubber farmers in both locations are following a staged process from hearing about clonal rubber and its high yield potential to the decision to adopt or not adopt in the end. The stage fits with the process of how people made decisions outlined by Rogers (2003) and Gladwin (1989a). Famers realised that the decision to adopt clonal rubber is a decision to change from existing practice. Some farmers were ready to change as information about new technology was provided and their situation supported their change, but some farmers, because of the constraints, chose to continue with their previous system. This study found different categories of rubber farmers regarding adoption of clonal rubber.

In the decision making in the households in Jambi and also West Kalimantan men and women make decisions together. However, from a gender perspective, sometimes when the men have the main role in rubber management the role of women is unrecognised as men are more dominant than women in decision making. In reality, the role of women in adoption of clonal rubber is important and their role in enhanced rubber productivity also will increase in the upcoming years. This is similar to the agricultural sector, especially when the farmers need to do more intensive on-farm activities in order to increase their income to support the household (Vanclay, 2002). Therefore, in order to increase the adoption of clonal rubber and rubber production, the government, especially in extension, needs to recognize that women are an important part of rubber activities and it has to consider how the women can be involved in the project. Women's groups in Bungo and Sanggau should be involved not only in agricultural activities but also in rubber agroforestry. For example by inviting women to be actively involved in the village meetings and training related to development of clonal rubber. In addition, training or intensive workshops are required so men will more exercise gender sensitivity in decision-making circles at the village level or higher (de Vries and Sutarti, 2006).

Some of the conclusions of this study may only apply to the rubber farmers in the locations of this study. Further exploration and modification are needed for different locations in which farmers have different social, cultural and economic resource access, and different motivation and constraints. However, some criteria recognized in this study were common factors that are found in other studies of the adoption of agricultural and forestry technologies. These factors included the expectation of increased profit, availability of capital, availability of land, incentives, labour, knowledge, information and technical assistance. Therefore the decision tree models in this study also can be applicable to adoption studies for different groups of farmers.

9.3 Implications and Recommendations for Government Policy

It is well known that the adoption levels of new agricultural technologies can be improved with appropriate policies and institutional support. Although there has been a general recognition of the importance of rubber agroforestry in most provinces in Indonesia, supportive policies for this agroforestry system remain limited and government programs to support the development of rubber smallholdings are still few. This can be seen from the percentage of rubber farmers or areas that have been covered by government improvement projects.

This study found the main similarity of characteristics of the communities in both locations was they were still dependent on natural resources such as jungle rubber and subsistence agriculture to meet their needs. As they needed to increase their rubber production, dissemination of clonal rubber with potentially high yield to replace the unselected and low production local seedlings was popular among farmers in both communities. Therefore the potential for adoption was high, especially if the constraints were addressed through more carefully targeted policies.

The study also shows that the criteria in the decision making process are also revealed to be interconnected and, consequently, a comprehensive integrated solution was required to increase the adoption of clonal rubber. This information is important to understand the farmers' strategies in dealing with their constraints and limitations in making adoption decisions. Putting these factors and processes into policy and technical implementation may increase the effectiveness of the diffusion of clonal rubber and may increase the number of adopters.

The analysis of this study suggests some of these recommendations are not only beneficial for improving dissemination of agroforestry technology in Indonesia but also in other developing countries. Several implications and recommendations resulting from this study are presented below.

1. A new technology has to be better than the current or previous practices. In the case of clonal rubber, it should be better in growth, yield, production age and resistance to pests and diseases. Diffusion of innovation theory mentioned that

the new technology will be adopted if it is understood as being better than previous practices in terms of economic profitability, social prestige, cost efficiency and benefits, and people's satisfaction (Rogers, 2003). The farmers who have seen that clonal rubber is better than local rubber were confident they should adopt it. However, the failure to show the advantages of clonal rubber in some demonstration plots in Jambi affected the perception of other farmers. In addition this negative perception spread easily as the other farmers who had not seen the demonstration plots referred to getting information from their neighbours. Further as neighbours have an important role as sources of information in both locations, the farmers might use the information from and observation of their neighbours as a base for their decisions.

Recommendation:

The projects have to convince the farmers that the new system is superior to the existing system. Demonstration plots or off farm trials have to be established carefully in locations that are biophysically and culturally suitable for the growth of clonal rubber. Good quality examples of implementation from research stations must be suitable for real farmers' situations. To follow the establishment of demonstration plots, field researchers and extension workers should work more closely with the farmers. They should disseminate technical information to the farmers and provide ongoing effective and accurate information, so that the farmers can learn from the demonstration plots. To deal with problems that arise after establishment of demonstration plots, extension workers have to be more active and available in the field to provide reliable information.

2. The new technologies should also be compatible with the farmer's objectives and have fewer risks. The application of clonal rubber seems to be compatible with the objective of rubber farmers to increase their income, however it has high risks. In the case of Jambi which is environmentally and culturally suitable for wild pigs, planting clonal rubber has been seen as having more risks rather than planting local rubber. Risks and uncertainty caused by pests were the main constraints for non adopters in Jambi, reducing the attractiveness of clonal rubber.

Recommendation:

Presence of pests such as wild pig and monkey in Jambi is likely unavoidable. Farmers become more concerned about the damage to their rubber seedlings by pests once they have planted high value clonal rubber. Farmers think that losses of their clonal rubber can affect their economic livelihood. To reduce these risks farmers have to plant clonal rubber close to their village where there is less risk of wild pig and monkey attack. However because of scarcity of land, the location of new planting is mostly far from the village. This area could be more high risk for pest damage. Therefore rubber in this area should be fenced in, large-diameter rubber stumps should be used or farmers should stay regularly on the plot to guard seedlings. More study of behaviour of vertebrate pests should be commissioned to find more effective solutions. Local government should consider working together with tourism operators and private hunters and use pig hunting as a sport to reduce the wild pig population.

3. This study shows that lack of capital is still the main constraint in the adoption of clonal rubber in Jambi and West Kalimantan. The farmers have difficulties buying those items necessary to start the establishment of clonal rubber plantation such as clonal seedlings, fencing, fertilisers, pesticides and herbicides. Difficulties getting cash during waiting periods are also important for farmers who do not have more land or additional income sources. Local governments already promote clonal rubber plantations through various schemes, providing free or subsidised planting material and fertilisers or easier access to credit and technical information. Incentives and credits have been found to influence the adoption of new technologies in agriculture (Feder et al., 1985; Holden et al., 2004; Shiferaw et al., 2009) and in adoption of clonal rubber in Malaysia (Sail and Muhamad, 1994). However, the incentives and credit schemes given to the local farmers in the study area were limited or ineffective. Only a small number of farmers have got incentives or credits from government. From field observation it was found that incentives, especially temporary incentives such as clonal seedlings or cash were not effective without the continuous assistance of field officers or extension workers. It was also mentioned by Potter and Lee (1998) that receiving credit has not helped smallholder rubber farmers to adopt

new technologies when extension services or materials are not available in the local communities.

Recommendation:

Incentives may increase the adoption of new technologies. The Government needs to provide more incentives and access to credit to fulfil the requirements of the development of clonal rubber plantations. The incentives could be free clonal rubber seedlings and other production inputs such as fertilisers and pesticides to start clonal rubber plantations. The credit can be cash that can be used for land clearing, fencing and planting as well as purchasing input resources. Or the Government could create a climate which encourages other institutions such as farmers' groups and NGOs to create credit systems such as the Credit Unions in West Kalimantan to provide more access by farmers to credit. The government may encourage farmers in Jambi to create their own credit system like in West Kalimantan.

The access to capital sources such as credit also should be improved with simpler mechanisms that suit the schedule of cultivation of clonal rubber. This will enhance farmers' ability to get capital to start high yield clonal rubber for their rubber plantation. In addition the Government needs to make better incentives and credit systems with a combination of financial and technical incentives. Ongoing assistance is needed including during the period of establishment of the plantation, the immature period, the time of tapping and also for marketing. This assistance would direct farmers to persist in planting clonal rubber even if there are no further projects or incentives as it will prevent farmers losing motivation and provide the ability to keep maintaining their clonal rubber rather than dropping out because of lack of resources.

4. Lack of technical knowledge in the implementation of clonal rubber still appeared to be a constraint in Jambi and West Kalimantan. Supriadi and Chamala (1992) in their study of the adoption of new technologies by rubber farmers in Sumatra also mentioned the same constraints. Some farmers still lacked the technical know-how for planting and managing clonal rubber. ICRAF and also local government has been providing training for rubber farmers in

various related subjects, however compared to the number of smallholders very few rubber farmers have received training. In addition, there were also few applications of technical knowledge on their land by trained people. This indicated that the quantity and quality of training need to be improved. Since farmers vary in their socioeconomic backgrounds, education levels, age, experience, learning needs and problems, diversity of approaches is important. The new technologies should be communicated to the farmers using proven extension education principles and suitable methods for training. People who get trained are more likely to adopt the technologies than people who do not. For example, in his study in the Southern Philippines, Cramb (2004) found that training was the most influential factor which increased the adoption of new technologies. And the importance of training in adoption has also been highlighted in various studies (Chi and Yamada, 2002; Ghadim et al., 2005; Mercer, 2004; Sunding and Zilberman, 2001). For this reason methodologies and sources are important in the effectiveness of training.

Recommendation:

Successful application of training in the field depends on the nature of extension activities. Farmers need easy access to competent information and assistance in the beginning and during the diffusion process. The extension workers may provide advice and information to assist farmers in making decisions regarding adoption of new technologies. Improvements of the extension system are needed. These include enhancement in the numbers of extension workers in the field to keep farmers informed of the current information and continuous assistance. Extension workers should work together with researchers who have capability to do research and development for better and more adaptable technology as well as providing technical information. These approaches may improve the motivation of farmers to adopt clonal rubber.

5. This study found that unavailability of good seedlings affects farmers' clonal rubber planting decisions. The farmers were very interested in planting clonal rubber, however –especially in Jambi - reliable planting materials were often unavailable or too expensive.

Recommendations:

Various training programmes have been introduced by local government and ICRAF regarding preparation of clonal rubber planting materials. The local governments need to encourage rubber farmers to produce clonal rubber seedlings by providing more financial and technical support for rubber farmers to produce their own seedlings. Technical knowledge of producing planting material is an important element for rubber farmers to produce clonal seedlings. Training for farmers on the preparation of clonal rubber planting material in their own land or as collective nurseries in farmers' groups has to be increased. This training will encourage rubber farmers to produce their own planting materials and to guarantee the availability of high quality clonal rubber for themselves and other farmers. Availability and access to the clonal seedlings seemed to increase the adoption of clonal rubber by these farmers. The example of farmers in Pana village who built their own nurseries can be used as a role model

The Government, non government organisations and the private sector also need to increase access to affordably priced clonal rubber seedlings. To support the production of clonal rubber seedlings and also other inputs for clonal rubber development, the government also needs to increase infrastructure. The government has to increase investment in public infrastructure such as roads, communication facilities, transportation and markets.

6. Farmers' groups have an important role in the adoption of clonal rubber. The farmers' group format provides information exchange and improves dialogue between farmers which leads to improved efficiency of resources and improved linkages between farmers, extension workers, researchers and government staff.

Recommendation:

Training in technical knowledge is important however it is also important that the farmers are provided in training to increase their skills in forming farmers' groups, developing leadership and management of farmers' group. This training may empower local groups to increase their solidarity and self-confidence and sharing of responsibilities in the farmers' group activity. Further it may help farmers to develop their capability in working together to deal with constraints to increasing their rubber productivity.

7. ICRAF is interested in improving rubber production by incorporating clonal rubber in the rubber agroforestry system for the purpose of attaining a balance between production and conservation. Meanwhile the Government is more focused on production efforts on plantation species with a monocultural system rather than an agroforestry system. At the village level, in some cases this different context of application confuses some farmers who want to adopt clonal rubber. This study has shown the need for stronger relationships, common understanding and consolidation between researchers, government officers, extension workers, NGOs and the farmers in the dissemination of new agroforestry technologies. Potter and Lee (1998) emphasized the importance of collaboration of government, international donors and NGOs when promoting projects of rural development such as the introduction of clonal rubber to improve smallholders' daily life. NGOs have an important role as intermediaries when the farmers have doubts about the government's projects because of past mistreatment (Marsh, 2002).

Recommendation:

ICRAF has limitations in developing more demonstrations of clonal rubber or introducing more incentives, as it is mostly involved in research. Also it cannot call for more adoption if it does not have linkages to the other projects, institutions or other related government agencies. This is because their project was limited and emphasised farm or demonstration plots. A program of introducing clonal rubber including incentives, credit and assistance for farmers has to be integrated in the development plan of local government. It is very important for the International Centre for Research in Agroforestry (ICRAF) to increase its partnership with the local government projects and also extension services. It was shown in this study that training was more available in West Kalimantan, as local governments and more NGOs provided training.

9.4 Implications for future research

This study has some limitations and some aspects of the results need further study and exploration. These were mainly because of the limitations in time and the costs of the researcher during research. Overall, this study provides support for further research into the adoption of clonal rubber and a recommendation to promote its use among smallholders in Jambi and West Kalimantan. Research designed to increase the adoption of clonal rubber should focus on a deep analysis of the role and influences of family in the decision making process, especially where decisions would affect their family life.

This study did not observe and include the role of gender in the decision making system. Women as wives and also as farmers are influencing household decision making. Their roles may affect men who may be considered as leaders of households who perceived themselves have final responsibilities for decisions regarding adoption of clonal rubber and may provide additional potential criteria or limitations to adoption that were not directly addressed by this study. In-depth study and analysis is required of the way gender, land tenure and wealth effectively influence the farmers' decision to adopt new technologies in Jambi and West Kalimantan.

In the future, the choice for farmers will be more varied. There are some income choices for farmers of other commodities in the locations of the study beside rubber such as oil palm plantation. Before oil palm was developed, farmers in Bungo and Sanggau depended mainly on rubber for their income and paddy rice for their own consumption. Some farmers were looking for alternatives to maximise their profit from land. Oil palm plantation for example, provides more access to big companies, is more profitable, uses less labour, and has high returns and investment (Feintrenie et al. 2010). In addition, oil palms are more aggressively established by big private companies and supported by local government for local economic improvement. For rubber farmers, profit is an important motive but not the only one. In the two locations of study, the farmers generally let their un-productive land, old jungle rubber and land that was far from their village and lacked transportation access be converted to oil palm plantation. The farmers in Jambi and West Kalimantan preferred to use their land that was closest to their village for intensive clonal rubber.

The farmers in West Kalimantan considered income from oil palm as complementary to their income from rubber, especially when the rubber price was getting down. This could be changing in the future, as oil palm is mainly managed by big companies and transmigrants, with some local farmers starting to develop their own independent oil palm plantation (Feintrenie et al. 2010). This occurs even though conversion of forest to the monocultural oil palm plantation causes the loss of some forest biodiversity and environmental services. As this study did not make detailed comparison with the profitability of other commodities, this topic could benefit from further study.

The other implication of this study is the importance of the relation between the adoption of clonal rubber and deforestation in Indonesia. As we know, deforestation is one of the big problems in the forestry sector in Indonesia. The causes of deforestation are varied, namely human activities such as illegal logging, forest conversion and natural disaster. Even though illegal logging and forest encroachment happened to be the major deforestation drivers in Jambi and West Kalimantan and generally, in other provinces in Indonesia, conversion of forest area to plantation also has to be put into the account. Large scale conversion of forest to plantation estate such as oil palm and rubber plantation for economic purposes may increase deforestation. In the past, in comparison with other forest conversion, such as oil palm, coconut, coffee, cocoa or pulp trees plantations, rubber agroforestry systems are the best in maintaining a certain level of biodiversity (Penot, 2004). However there is the possibility that the high prices of rubber latex or oil palm plantation will inspire farmers to expand their rubber area and convert their forest or old rubber agroforest to monoculture system to improve their productivity. More study and analysis is required into the topic of how increasing financial returns from rubber influence decisions and behaviour of smallholder farmers and other stakeholders in rubber production in Indonesia. This study would examine the relation between conversion of forested area to expand rubber plantation and the overall contribution of rubber agroforestry to relief of deforestation issues in Indonesia.

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